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THE MODERN TERROR OF THE DEEP

A Brief History of the Development of the Submarine With an Analysis of the Present Types, Their Powers and Limitations

STAFF ARTICLE

To the casual reader of the daily war news the word "submarine" conveys the idea of a type of craft of unknown dimensions that is capable of dealing, single handed, with battleships of the largest and most formidable type. Day by day we hear of the sinking of trawlers, merchantmen, passenger liners, and occasionally ships of war by these unseen terrors of the deep. No one doubts the effectiveness of this recently developed arm of the modern navy, but it has come into prominence so rapidly that we are inclined to think that the birth of the idea of such craft dates back but a few years.

The first form of the submarine was the diving bell used in the time of Alexander the Great. In 1850, William Bourne, an Englishman, is said to have developed the idea, constructing a more mobile form. Of either of these little is known, however. The reign of James I. saw the further evolution and it is stated that that monarch was a passenger in a boat built by Cornelius Van Drebbel.

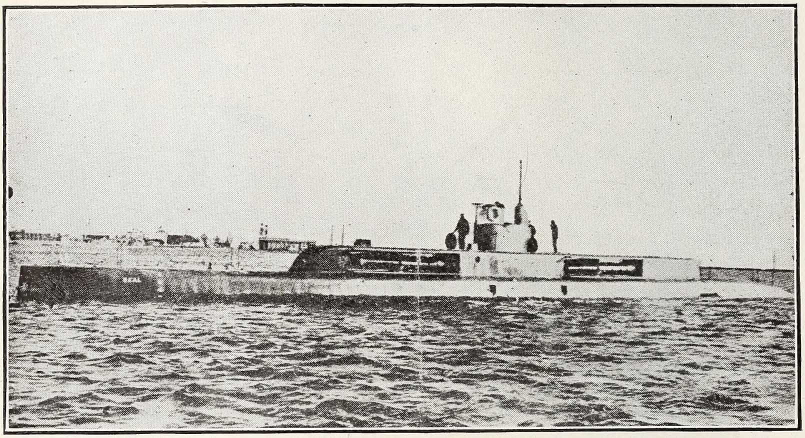
As an actual weapon of war the submarine was used in an attack on the British Battleship Ramilles off New London. This boat was of ovoidal shape, flattened at the sides and had a conning tower large enough to admit a man's head and shoulders. The crew consisted of one man, the pedal extremities of the observer being the motive power. By means of foot cranks the boat was propelled at a speed of from two to three knots. The striking power consisted of a wooden magazine fastened to the after, upper part of the hull. This carried about 150 pounds of gunpowder and was detachable. A screw, capable of being turned from inside the boat and arranged so that the outer portion could be let go forced the iron-clad magazine through the hull of the hostile craft, where it was caused to explode. The first attempt on record, that of the attack on the Ramilles, was a failure owing to the copper sheath on the hull preventing the operator of the submarine from driving his weapon home.

Between 1796 and 1810 Robert Fulton built several boats, but died before his last effort was given a trial trip. It was 80½ feet long and was propelled by a steam engine. Shortly after this the first

boat to use compressed air as motive power was built in France by Charles Brun.

In 1896 two forms of propulsion were used for the first time by M. Lanbeuf. This gave rise to the distinction between the "submarine" and the "submersible."

While all the previous attempts were more failures than successes, they laid the foundation for what may be called the modern submarine, which was first built by J. P. Holland, of Paterson, N.J., in 1899. The Holland Type of submarine is one of those used at the present time, although of course greatly developed. In 1901-1902 seven of these were launched by the United States. Their general dimensions were—length, 63 feet, 4 inches; beam, 11 feet, 9 inches; displacement, 120 tons; Gasoline engines were used when travelling



Lake Type of Submersible

on the surface and electric motors when submerged. They attained a speed of 6½ knots under the surface and 9 knots with decks awash. At this speed the radius of action was 400 miles.

As now used by the great powers there are two distinct types of under water boats. The "Submersible" is built primarily for work on the surface but is capable of being submerged. The "Submarine," on the other hand, comes to the surface only to make observations, attack by means of disappearing guns or to receive a fresh supply of air. Hence the forms of the two types differ. The submersible is built with a hull conforming to the general lines of the ordinary surface vessel, while the submarine is cigar-shaped.

The ship-shaped form of the submersible is, however, attained without abandoning the advantage of the circular section which is maintained throughout an inner spindle-shaped "strength-hull," being the form best adapted to resist the pressures of the water. Between the inner and the outer shell are water-ballast tanks and oil tanks, whence the strength-hull may be of small diameter well suited to resist great pressures without going to excessive scantlings.

The other hull, not being exposed to great pressures, may be lightly built, but will yet in some measure protect the inner hull against damage by collision. The ballast and oil tanks may, with a relatively small addition in hull weight, be made very large, whence a great reserve buoyancy and great radius of action can be secured. In a submarine the tanks are chiefly inside the strength-hull and cannot, therefore, be very large without unduly increasing the diameter of the hull and hence its tendency to collapse.

Speaking broadly the submersible has better sea-going qualities, and higher speed on the surface than the submarine, but the form is not so favorable for driving under water.

The reserve buoyancy in the early submarines was only about 5 per cent. of the light displacement but has been gradually increased to about 18 or 20 per cent. In submersibles, on the other hand, the reserve buoyancy has been reduced from about 72 per cent. in the first boat of this type, the French Narval, to about 35 per cent. or less in recent boats.

The submersible, as, for instance, the Germania type, has a relatively high centre of gravity and hence small stiffness in submerged condition on account of the high position of the tank structures, while in the surface condition the stiffness is in some cases excessively great due to the large area of the waterline. The submarine, exemplified by the Holland boats, has a low centre of gravity on account of the low-lying water tanks and therefore great stiffness in the submerged condition, but small or moderate stiffness on the surface. The Laurenti type, where the ballast tanks are partly below the strength-hull, partly above or, at least, very high, are intermediate between the Germania and the Holland type in this respect.

In order to obtain sufficient stability in the submerged condition submersibles must generally carry a considerable amount of keel-ballast. This of course is a drawback, but also most submarines carry some ballast. Part of the ballast is generally detachable, often referred to as a "safety keel," to be let go in case of emergency. In passing from the light to the submerged condition and vice versa a point will exist where the stability is a minimum, being reduced by the presence of free water in the tanks. The designer must, therefore, carefully determine the conditions of stability in all intermediate positions in order to satisfy himself that a proper metacentric height is always maintained. If the stability vanishes at any point the boat may heel over to a considerable angle before equilibrium is restored, or may even capsize.

The hull of a submerged vessel is exposed to an external water pressure which is directly proportional to the depth of immersion. Already at a depth of 200 feet the pressure is about 100 pounds per square inch, and since the depth of water in the ocean is generally more than ten thousand feet, boats cannot be constructed to withstand the pressures at all depths which they may encounter. It is therefore necessary to assign a limit to the head which a boat is required to resist. Generally there will be no object in going deeper

than required to clear the bottom of vessels on the surface, that is to a depth of about 75 feet, but accidentally boats may descend involuntarily to greater depths. Usually the head to which boats are tested is about 150 feet, in the United States Navy it is 200 feet. A certain margin of safety is, of course, applied in the construction, but if a boat goes much beyond its test depth it is liable to collapse. In most boats the strength-hull is made of circular section as stated above.

Navigation

Steering in a horizontal direction takes place as in ordinary vessels, but steering in the vertical plane has caused many difficulties to early inventors. Mr. Holland introduced diving and emerging by inclining the boat at considerable angles, while most other inventors preferred to keep the boat as nearly as possible on an even keel and to effect great changes in depth either by pumping water in or out of the boat, or by means of horizontal propellers, or by so-called "hydroplanes." The last method appears to be that which is mostly used in submersibles. Hydroplanes are similar to rudders, sometimes fitted amidships abreast of the centre of gravity of the boat, sometimes placed forward and turned the same way as the aft rudders. In all cases the object is to produce an upwards or downwards force driving the boat up or down parallel with iteslf. This method is generally considered safer than the "porpoising" used in the Holland boats. Once the desired depth is attained, it is preserved by means of the horizontal rudder in the same way as when steering a course on the surface, but with this difference that even small deviations from the given course line (depth) are not here permissible. For guidance in steering a depth gauge and a clinometer are used. Steering in the vertical plane requires considable skill and experience.

In order to navigate, the submarine boat must be provided with a reliable compass and, even when submerged, a view of the horizon must be obtainable at any time. An ordinary magnetic compass is not quite reliable even when placed in a conning-tower of bronze, but recently the advent of the gyro-compass has provided a means of accurately determinating the direction independent of magnetism. The faculty of vision when the boat is submerged, as it must be when making an attack, constitutes one of the most important and difficult problems connected with submarine boats. The water is practically opaque and it was therefore necessary in early boats, when going under water, to emerge from time to time so as to obtain a view from the conning tower, but evidently this mode of navigation was anything but safe since the presence of the boat was thus revealed to the enemy. Already in the eighties and nineties optical tubes were introduced of simple construction, invented by Marié Davy in 1854 and gradually perfected. In its simplest form the optical tube had a mirror at each end inclined at 45° to the axis. The tube, being fitted watertight in the top of the boat, projected a few feet above water when the boat was immersed and thus a view of the horizon might be obtained, but the arc of

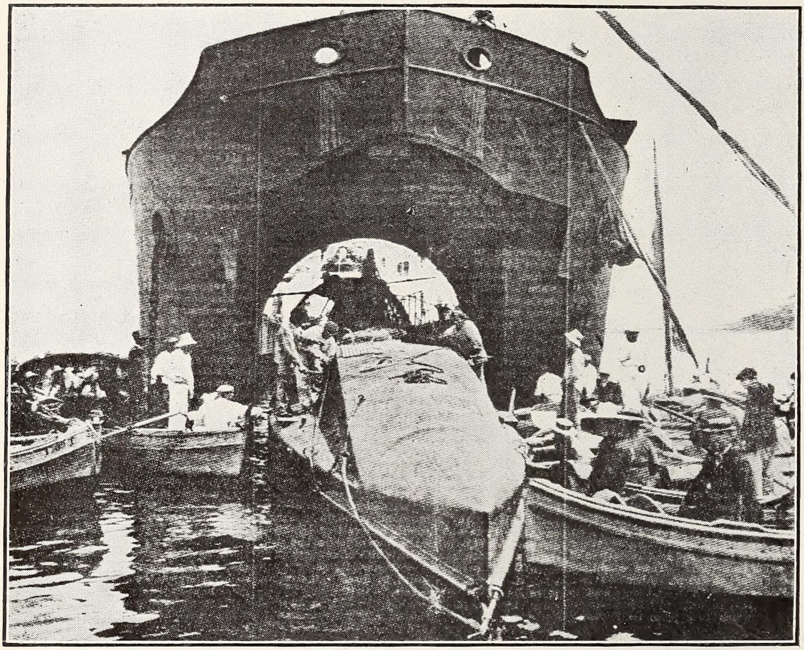
vision was at first only one or two degrees, and the image was very imperfect. The mirrors were replaced by prisms, lenses were introduced, and during the nineties several improvements were made, but not till about ten years ago was any serious progress made. Then, in a few years the optical tube or "periscope," as it is now usually called, was developed to a high degree of perfection, enabling the submarine boat to perform attacks without showing anything but the top of the periscope occasionally above water, at the same time obtaining a perfect view of the enemy. The improvements comprise a larger field of vision spanning an arc of more than 50°, as large or greater than that of the human eye, convenience of observation, and the addition of means for measuring distances and indicating directions. The magnification of the object is only about 1.5, which is found to give to the observer the same impression as when using the naked eye. By using the utmost refinements of optical art and science a perfect image of unsurpassed clearness and distinction is obtained. Mechanical power is employed for handling the tube, enabling it to be pushed up and down readily and quickly and to be turned round its axis. The length of modern tubes is up to 25 feet with a diameter of about 6 inches. The head of the tube projects from 10 to 20 feet above the hull. Difficulties still exist due to the vibration of the periscopes and spray on the front glass, but they are of secondary importance. Instruments have been constructed by which an all-round view of the horizon can be obtained without turning the tube, but have not proved quite satisfactory. The perfection of the periscope was the last link in the chain of inventions and improvements that were needed to endow the submarine boat with positive military value.

In order to go from the light to the submerged condition and vice versa it is necessary to admit or to discharge water. Main tanks of great capacity must therefore be fitted, provided with large sea-valves and powerful pumps. The water may if desired be forced out of the tanks by compressed air. The time occupied in passing from the surface to the submerged condition should not be more than about from four to five minutes. This, of course, is a point of great military importance. When a boat is completely submerged the main tanks are always entirely filled, and its weight is generally so adjusted that it falls a little below the buoyancy, leaving a tendency for the boat to rise to the surface. This tendency is overcome dynamically when the boat is in motion either by a slight inclination of the axis or by hydroplanes. The fine adjustment of the buoyancy takes place by means of a central auxiliary tank of moderate capacity used to compensate for incidental disturbing causes, such as variation in the specific gravity of the sea-water or consumption of stores. Smaller tanks near the ends of the boat permit an adjustment of the trim. Special tanks are fitted for compensating for such definite changes in weight as when a torpedo is fired and another inserted in the tube. A considerable amount of buoyancy can be obtained almost instantaneously by the release of of a safety-keel consisting of detachable blocks of lead ballast which are let go in case of emergency.

The superstructure which is above water in the light condition is self-bailing. In some boats it is built entirely and permanently open, serving only to provide a raised platform, but in most boats it is a watertight structure provided with large and numerous valves that can be readily closed when the boat is in light condition whereupon the superstructure will add to the reserve buoyancy and the stability.

Habitability

Space is always restricted in a submarine boat. When going on the surface the motor gives off much heat and requires a great amount of air for its combustion, carbon monoxide and carbonic acid, leak out from the engine. Also the men consume oxygen and



A French Transport Ship for Submarine Boats

produce carbonic acid, and when charging the batteries free hydrogen is liable to be liberated, forming with the air in the boat an explosive mixture and carrying with it particles of sulphuric acid. Where the fuel is gasoline or other volatile oil, it will evaporate at a low temperature and is liable to leak out into the boat; it is poisonous and capable of forming an explosive mixture with the air. For these reasons, it is necessary to provide a very vigorous ventilation when going on the surface. In the submerged condition, the problem would appear to be even more difficult because the available air is gradually vitiated, but it is found that with proper precautions

the crew can live for twelve hours or more without any sort of air renewal or means of purification. This is due to the constant leakage which takes place from the compressed air system, a leakage which can never be entirely prevented. If desired, the carbonic acid which gradually accumulates due to exhalation may be removed by chemical means or the foul air may be pumped out. Fresh air can be supplied as desired from the compressed air reservoirs or pure oxygen may be added. There is, however, rarely occasion for resorting to such means except in case of serious accident. A greater difficulty is the escape of gasoline and poisonous fumes from the motor as well as from the battery. There is no convenient test for carbon monoxide suitable for use in submarine boats, whence it has been necessary to use white mice for indicating the presence of this poisonous gas to the effects of which these little animals are very sensitive. White mice breathe much more vigorously than human beings and will absorb carbon monoxide about twenty times as rapidly as man. Hence, long before man feels any discomfort, the mice will show symptoms of distress. When this occurs and, especially when the mice become asphyxiated, it is necessary to ascend to the surface and to renew the air in the boat.

Life on board a submarine boat is very fatiguing and for this reason the time in which a boat can stay away from its base is very limited. The crew has to be changed at frequent intervals or it must be given time to recuperate, a fact which in many cases may limit the practical endurance of the submarine boat more than the supply of fuel. Under war conditions the crew of a submarine boat ought probably to be relieved after a few weeks' service, depending of course on the size and design of the boat and on the climatic and military conditions.

Means of Propulsion

For propulsion on the surface the gasoline motor was the first really successful engine. It was light, occupied small space as compared with the steam machinery and the combustion of fuel oil was not more than about one-half pound per H. P. hour as against at least 1½ pound per H. P. hour for steam machinery. For small boats, of a displacement of from 100 to 300 tons, where weight and space were very restricted, the gasoline engine offered the best solution, but the dangers from this volatile oil soon made it necessary to introduce heavy-oil motors, although they were in several respects inferior to the gasoline motors. While the latter are easy to start, special means are required for starting the former, and the consumption of fuel in heavy-oil motors such as those of the Koerting type was about twice as great as in the gasoline motors. The last step in the development was the introduction of the Diesel engine which likewise burns heavy oil. Although in itself rather heavy, it has a consumption of fuel somewhat less than that of the gasoline engine, and this is its principal advantage. The nominal radius of action of recent boats of the largest size, driven by Diesel motors, is given as about 3,000 miles. The speed on the surface has attained

16 knots in several boats and the designed speed in some boats now under construction is 18 or 20 knots.

The Diesel engine, then, is the motor which today finds most favor in submarine boats, but with the increasing size of boats and the claims to higher speed it becomes increasingly difficult to produce motors of this type of sufficient power. Units of from 1,300 to 1,500 H. P. with a power per cylinder up to about 200 H. P. are under construction and there are usually two and in some boats three propellers. Many difficulties are met with and failures have occurred whence steam power has been preferred in some boats as for instance in the French submersibles Gustave Zédé and Nereide of 1,000 tons displacement, which are to make 20 knots. Steam machinery has the advantages of reliability and durability, but it occupies more space and it is difficult to get rid of the heat. The radius of action obtainable with steam power on a given supply of fuel is much smaller than with Diesel motors. The weight of Diesel engines as fitted in submarine boats is about 65 pounds per H. P. as compared with about 50 pounds per H. P. for gasoline engines and from 50 to 60 pounds per I.H.P. for steam machinery inclusive of auxiliaries, propellers and shafts. The Diesel engine is being steadily improved and will no doubt be successfully adapted for larger powers in the submarine vessels of the future, but as the size and power increase, the relative advantages of steam machinery will become more pronounced.

For underwater propulsion, electric power derived from a storage battery of lead accumulators still offers the best solution. Since the first appearance of these cells they have been improved upon in many technical details, and are now reliable and durable. They will stand complete charging and discharging more than 400 times and may be expected to last about five or six years under ordinary service conditions in peace time, provided they are carefully handled. The weight per H. P. hour including outfit is by discharge in 3½ hours about 80 pounds, practically the same as in the early accumulators. Lead cells permit great variations in power and are at their best at low rates of discharge, a most valuable quality for submerged work. They can be stowed low in the boat and add thus considerably to the stability. They occupy about .4 cubic feet per H. P. hour, i.e., less than any other source of energy at present available for this purpose.

Attempts have been made to introduce accumulators of different type, the most promising of which are the Edison alcalic iron-nickel cells which have now come into serious competition with the lead cells and are to be tested in practical service on board some of the United States submarine boats. Before the result of this experiment is known, it is difficult to judge of the relative merits of the two types. It seems certain, however, that the Edison cells are more durable but more costly than the lead cells.

The total accumulated energy by storage batteries is necessarily small and rarely allows more than a speed of about 10 knots for 3 or 4 hours. Recently boats have been designed for 11 or 12 knots,

The radius of action at maximum speed of large boats is about 30 or 40 miles, but at reduced speed a radius of about 100 miles is claimed for some boats.

The electro-motors including switch-boards and leads weigh about 80 pounds per H. P. The excessive weight of the plant for underwater propulsion is the more unfortunate, since the weight available for propulsion is already very small as compared with that in ordinary torpedo-boats. The reason for this is that the hull weight is relatively great, occupying about 10 per cent. more of the total displacement than in a torpedo-boat. Only about 40 per cent. of the displacement of a submarine boat can be devoted to machinery and fuel as against about 50 per cent. in a torpedo-boat. Moreover, the plant for underwater propulsion comes as an extra addition and is practically a dead weight when the boat is going on the surface. It is evident, therefore, that submarine boats can never compete with ordinary torpedo-boats in point of speed.

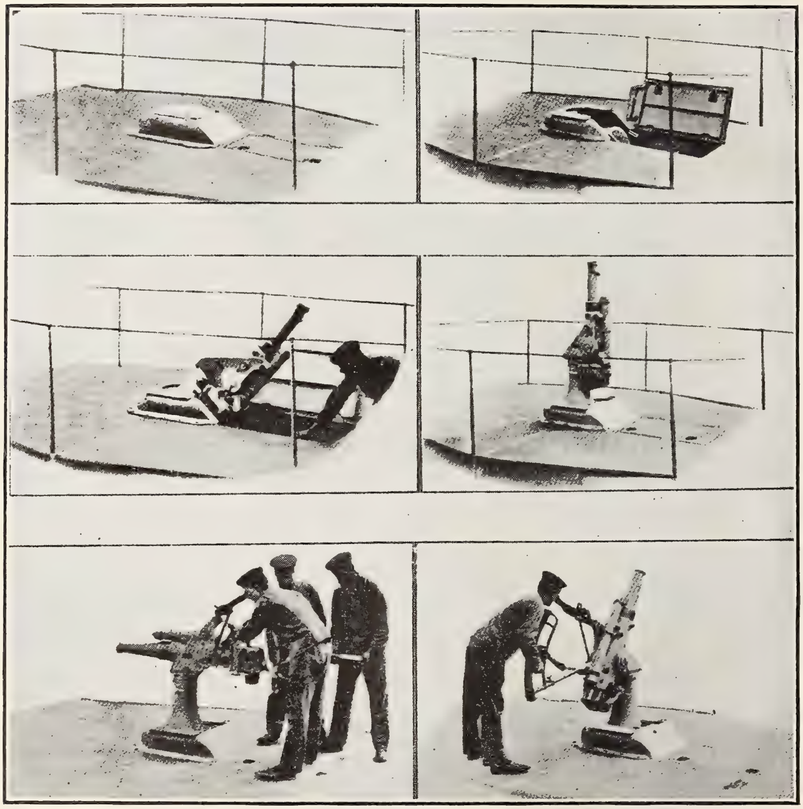
Great efforts are being made to devise a type of machinery that can be used both on the surface and submerged and especially one by which the propulsion under water does not entail any extra weight, but no satisfactory solution has yet been obtained. Any process based on combustion involves the storage of atmospheric air or oxygen, but a storage of these gases in sufficient quantities for underwater propulsion requires excessive weight and space. The discharge of the products of combustion is liable to reveal the presence of the boat.

M. d'Equevilley has proposed a solution which is being tried in the French submersible Charles Brun and probably also in a German boat. He uses an ordinary boiler with oil fuel and a steam engine on the surface, but when the boat dives under water the exhaust steam is led to a concentrated lye of sodic hydrate which absorbs the steam under strong evolution of heat and thus serves as fuel in a secondary "soda boiler." This process goes on till the lye is saturated. When the boat comes to the surface and steam is available from the primary boiler, the soda lye may again be concentrated by evaporation of the water which it has absorbed, and the boat is ready for another submerged run. This plan offers the advantages that there is no change of propelling motor, the same engine being used under water as on the surface, and there are no products of combustion. The machinery can be forced without difficulty and relatively high power attained both in light and submerged condition. No electric motor is needed. On the other hand, the system requires the addition of special soda-boilers and a hot water reservoir; the plant occupies so much space that the available weight cannot be fully utilized; the centre of gravity of the machinery is high and requires extra ballast to be carried; the radius of action on the surface is necessarily smaller than with an explosion motor, and there is likely to be a strong corrosion of the boiler due to the soda. The soda-boiler installation appears, nevertheless, more promising than other power plants so far proposed for this purpose.

Armament

The principal armament of submarine boats is the Whitehead torpedo. Recent English boats are said to carry six 21-inch tubes and French boats of the latest type eight tubes. Modern large boats are equipped with an armament of light guns in disappearing mountings. English boats carry two 3-inch or 4-inch guns so mounted that they can be used against air-craft as well as against other vessels. When not in use the guns and mounts are housed in the superstructure.

Attempts have been made to design mine-laying submarine boats, a problem which is evidently of considerable interest. As far



Disappearing Gun

as known, Russia was the only power that, prior to the war, had built a boat for this purpose, viz., the Krab, designed for dropping mines when in surface condition. It appears that the Germans are now following the example of Russia. A boat so designed that mines could be dropped when in the submerged condition would be

of greater value, but there are technical difficulties in releasing mines under water, in compensating for their weight and in determining their exact location. These difficulties have apparently not yet been overcome.

The faculty of communicating with other vessels, whether on the surface or submerged is one of great military importance for the submarine boat. For service on the surface wireless telegraphy has been successfully used for several years, but for submerged service it is only quite recently that means of signalling have been devised which promise good results. It was at first, when the submarine bell was invented, attempted to use it for signalling, but it was found that it was not well adapted for sending meassges by the Morse system. No practical solution was discovered till an European physicist showed the way by his experiments.on the transmission of vibrations through water. A wire of two inches in diameter was set into longitudinal vibrations by the friction of a hand-driven silk-wheel moistened with alcohol whereby a clear and sustained note was produced, capable of being sent in dots and dashes of the Morse code. The wire was fastened to a plate in contact with the water, and was anchored at the other end to some fixture. The tension of the wire was immaterial. An identical apparatus was fitted in one of the United States submarine boats in 1911 and readable signals were transmitted over a range of two miles. Still better results were obtained with steel ribbons and power driven exciters, by means of which distinct signals were transmitted over a distance of ten miles. Recently electrically worked oscillators have been used instead of the wire ribbons and have given very promising results. This mode of signalling is referred to as the "submarine wireless system," but it must be distinctly understood that the transmission through the water takes place entirely by sound waves emanating from a diaphragm plate which may form part of the ship's side. The receiver is a similar plate in another ship similarly connected. The invention seems now to have passed the experimental stage and signals have been transmitted under water without difficulty through a distance of fifteen miles.

As a consequence of the numerous and serious accidents which have befallen submarine boats of recent years much has been done to increase the safety of this craft. The hull is subdivided more minutely than formerly by bulkheads of sufficient strength to withstand the maximum water pressure. A buoy provided with telephone connection is fitted in the superstructure and can be sent to the surface in case of emergency, enabling communication to be established with the outside world. In some boats the men are provided with diving suits and helmets enabling them to escape or to remain for a longer time in the boat when it is flooded. Great precautions are taken to prevent the fumes from the storage battery entering the working rooms of the boat. The battery is in many boats placed in an entirely separate airtight well-ventilated compartment.

Vessels of special type, "salvage docks," are built for the pur-

pose of raising the boats when they have sunk to the bottom in damaged condition. Shackles are fitted on the top of the boats for this purpose.

Special vessels are constructed also for the transportation of submarine boats.

From the moment that submarine boats were taken into practical service, claims to increased sea-going capability, speed, radius of action, and better living conditions on board were advanced by the naval officers. Those claims could be best met by an increase in size and we can understand, therefore, that size has steadily increased ever since the beginning of the century. Boats were then less than 100 tons fully submerged and are now being built of about 1,200 tons' displacement. The reason why the displacement has not increased much faster is chiefly the difficulty of providing suitable motors for propulsion of sufficient power. By an increase in size, moreover, the boats become more difficult to handle under water, especially where the depth is small, but this difficulty is of secondary importance for ocean-going boats, which are likely soon to become a reality. The high cost of large boats will restrict their number, the price per ton being almost three times as high as for battleships.

Military Value

The great military value of submarine boats has been demonstrated in the European war. At the present stage of development submarine boats afford not only the best means of defence of one's own harbors and coasts, but may be used also for offensive purposes in the open sea and on the coast of an enemy up to a distance of at least five hundred miles from their base. The large boats of from 1,000 to 1,200 tons' displacement now under construction will have a still greater effective radius of action.

It is characteristic for the submarine boat that, once it has gotten into position, it can carry out an attack with relatively small risk to itself. In this respect it differs radically from ordinary torpedo-boats which must be prepared for great and almost unavoidable sacrifices in order to carry out a successful attack. The greatest difficulty with a submarine boat is to bring it into position for attack because the speed is relatively slow. The initiative of the commanding officer, the training, endurance, and discipline of the crew, as well as the condition of the boat and the machinery count more in submarine boats than in other warships.

The development of the submarine boat in the future is likely to be gradual. In the meantime, it is probable that also the means of attack and defence possessed by the battleship against submarine attack will progress. Evidently, the first point for the battleship is to detect the submarine boat before it has reached within striking range. If this is successfully accomplished, the attack of the submarine boat can generally be avoided because its speed under water is relatively slow. Detection of a submerged boat is, however, a difficult matter, the only visible point being the head of the periscope which needs to be shown above the surface only

from time to time. In still water the periscope is fairly visible by the wake which it makes on the surface when emerging, but in rough and misty weather it is extremely difficult to see. When the periscope is discovered, it will be at once subject to a hail storm of projectiles from light guns and, if it is hit, the boat will be blind and helpless. If, after that the boat shows the conning tower above the surface, it will be generally exposed to destruction by artillery fire.

Detection from seaplanes and other types of air-craft is under many circumstamces fairly easy and this mode seems to promise a great deal. These new engines of war may possibly become deadly enemies of the submarine boat by attacking it with bombs. When a boat is submerged it is quite helpless against such attack. Even very light bombs are likely to prove destructive, and since the aircraft is in no danger of counter-attack from the submarine boat, it can go very low and hitting should not be a difficult matter. The submarine boat cannot even observe a seaplane when immediately over it. A further development of the seaplane is, therefore, likely to prove extremely dangerous to the submarine boat.

No other type of war vessel has done anything approaching the same effective work as the submarine, and from a superficial survey of the whole problem, it might be thought that this has already once and for all, solved the question of the policy which must be followed in naval design in the future. It might, for instance, be deducted that we, among other nations, must concentrate upon the construction of submarines on an enormous scale, even to the exclusion of building large capital ships. Yet it is obvious, if the matter be carefully considered, that what is undoubtedly the correct policy for one nation would be quite inadvisable in the case of another. In particular a strong naval power must always keep the offensive most clearly in view, whilst a weak naval power must necessarily rely upon defensive tactics.

Submarines, if in sufficient number, can always prevent the approach of transports, although they cannot destroy the submarines opposed to them. In fact, it seems that by a combination of a large fleet of submarines, the prolific laying of mines, and effective fort guns, it will be almost impossible for any power, however strong it may be on the sea, to allow its fleet to cover the landing of an army upon hostile shores. In other words, the submarine has added so enormously to the defensive power of any nation that in course of time an invasion by sea will become an impossibility, even in the case of those countries with a very long sea coast and a relatively small fleet.

So much has the submarine thus altered warfare that, from the purely naval standpoint, the predominant sea power could never inflict a total defeat upon a minor sea power in the sense of so completely destroying the smaller navy that a landing on a hostile coast could be effected by its aid; for even the destruction of all the submarines—a difficult enough task—would still leave the mine-fields and fort guns.

The submarine will, therefore, have a very strong influence upon military tactics in the future, and in particular for those countries which do not adjoin other countries with whom they may, under any conceivable conditions, be at enmity. It follows from this that the submarine has practically rendered Great Britain immune from invasion under any circumstances, although it should be added that our submarine fleet has not yet attained such proportions as to guarantee this condition at the present time, and when it has there is always the distinct possibility that some new method of warfare will have been developed.

Submarines cannot destroy submarines, as battleships can destroy battleships, and according to past experience it is not by any means simple for any other type of craft to bring about the destruction of submarines in large numbers. It is true we can help in this direction slightly by building an enormous number of destroyers, but, on the other hand, these are costly vessels in comparison with submarines, and the number required is so very large that one doubts if this method of attacking the submarine problem will ever be carried out on such a scale as to give security of feeling against the depredations of the submarine. The point of importance to be noticed here is that, whilst surface vessels must almost invariably act in flotillas, except, perhaps, very fast destroyers, which can escape from any slower boats, the submarine works most efficiently in single units, and this has been well shown by the recent German tactics.

The time is already here, therefore, when we should consider to what end the path along which all naval progress is tending will lead. We must open our eyes to the dangers of the future, and make preparations accordingly, not after peace has been declared, and we find we have given away some important points, but long before the question of the terms of peace is even discussed.

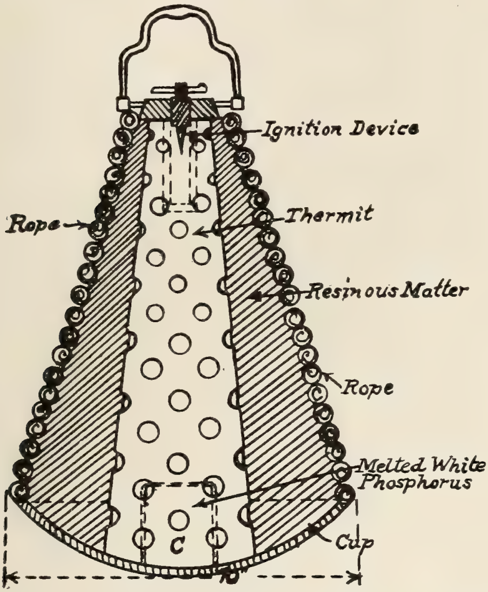
We must now and onwards continue to develop submarines in this country with more urgency than ever before, and not only must much larger numbers be built in view of possible contingencies, but progress must be made with the type of submarine constructed, particularly in the matter of speed (which means progress in Diesel engine construction), and also in the possibility of under-water craft taking the offensive on a large scale.

GERMAN INCENDIARY BOMBS

The British Fire Prevention Committee has investigated the various scenes of bomb raids in England, and has carried out tests, with the result that it has found out the nature of the bombs thrown by the aerial craft of the enemy.

An incendiary bomb is shown in section in the illustration herewith. The bomb is, as a rule, conical in shape, 10 inches in diameter at the base; it is corded around and has a metal handle at the apex. The base is a flat cup, on which a pierced metal funnel is fitted, provided at the top with an ignition device and a handle. The funnel is generally filled with thermit, which rapidly becomes

molten metal, having the extraordinarily high temperature of about 5,000 degrees Fahr. This molten metal spreads upon concussion. Outside the funnel is a padding of a highly inflammable or resinous material bound on with an inflammable form of rope. The resinous



material creates a pungent smoke. There is, further, generally some melted white phosphorus in the bottom of the cup which develops nauseous fumes. In some cases celluloid clippings are added, and occasionally a small quantity of petrol.

Fires caused by them, regardless of the extremely high temperature generated at the actual seat of the outbreak, may be prevented from spreading by applying water promptly, continuously, in large quantities, and under pressure.

LETTERS FROM GRADUATES

WHY?

The Editor—

Sir:—The "School" spirit is the strongest sentiment in the University. (We do not like the word except for its associations. "School of Science" is apt to mislead, it may be used to mislead, to emphasise a difference between "School" science and University science). Is the life of this sentiment within the individual only of four years duration, beginning in his freshman year and dying with his graduation? Is there a "School" spirit after graduation? How strong is it? How does it manifest itself?

Should there be a "School" spirit after graduation? Of what use is it?

Yours, etc.,

A Graduate.

THE HEAT TREATMENT OF STEEL

T. R. Loudon, B.A.Sc., A. M. Can Soc. C.E.

In the following discussion, it is not necessary to establish an elaborate definition of what is meant by "steel." A good general definition is that steel is the product of a process wherein the final metal has existed in a molten state and does not contain over 2 per cent. carbon. Such a definition may be disputed by the makers of the latest corrosion resisting "irons," but it should be recognized that these "irons" are merely steels very low in impurities. These arguments, however, need have no bearing on the following, because for all practical purposes as far as heat treatment is concerned, it is only the steels well known to commerce and always designated as such that need be taken into account. The only limitation that need be made in the discussion is that the carbon content of the metal must not exceed about 2 per cent. (theoretically 2.2%). Not that steels of such a high carbon content are of commercial value, but as will be seen, this is a rough limit that must be made if certain laws are to be applied—beyond this limit new conditions exist and the cast irons are dealt with.

Commercial steel ordinarily contains, besides iron and carbon, varying amounts of silicon, manganese, sulphur, and phosphorus, but the effects of these elements will be disregarded and the discussion limited to alloys of iron and carbon. It may be pointed out that for all practical purposes *this course of investigation may be pursued with safety as far as commerical steels are concerned.*

The effect of heat treatment on steel can only be understood when one has studied to some degree what is termed the *Iron-Carbon Diagram. It is not proposed in this article to go very minutely into the changes that take place in the constitution of steel during heating or cooling—rather merely to ouline the main changes and give the reader sufficient information to pursue the subject further should he so desire.*

The Iron-Carbon Diagram

Fig. 1 is a Temperature-Composition Diagram—The lines on this diagram are constructed by observing at what temperatures changes take place in iron-carbon alloys of known composition. When the positions corresponding to these phenomena are plotted and joined, the diagram as given is the result. These changes are observed by means of what are called cooling curves, which are merely time-temperature curves representing the rate of cooling. The drops in temperature during stated intervals of time are noted and plotted as a curve, and it is observed that the rate of cooling changes at certain points, in some cases the temperature remaining constant during quite an interval of time. For instance, it is found that when molten metal begins to freeze, quite a change in the cooling curve is seen. In the solid state as the metal cools, other changes in the curve are noted, which on investigation are seen to represent certain internal adjustments which are of the greatest practical importance. It is usual to investigate alloys while cooling,

but the changes noted during cooling will take place in the reverse order during heating, although the temperatures at which they take place are generally not quite the same as when cooling.

Applying to steels the method of investigation just described, if iron-carbon alloys of various known compositions be taken and melted and allowed to cool and the temperatures at which freezing (solidification) begins noted and plotted on a temperature-composition diagram, the lines *AZ* and *ZP* will result. Carrying the investigation a little further and noting the temperatures at which these same alloys are quite solid and plotting these temperatures on the ordinates representing the alloys to which they belong, the lines *BX* and *XZ* are obtained. To illustrate this, consider a steel of 1.5% carbon whose temperature line is represented by the ordinate *QT* drawn from 1.5% carbon on *OW*. This steel will be molten at any temperature above *Q*. At *Q* the metal begins to freeze and will continue to freeze till the temperature corresponding to *R* is reached, when the metal will be entirely solid. Reversing the process, the metal would begin to melt at the temperature corresponding to *R* and would continue to melt till the temperature corresponding to *Q* is reached, when all the steel will be molten. This illustrates roughly the freezing or melting of any iron-carbon alloy. To sum up; at the lines *AZ* and *ZP* freezing begins and at the lines *BX* or *XZ* freezing is completed; reversing the process, melting begins at *BX* or *XZ* and melting is completed at *AZ* and *ZP*. It is seen from the diagram that low carbon steels do not melt as readily as high carbon steels and that the cast iron containing about 4.3 per cent. carbon has the lowest melting point of all steels and cast irons.

It is well known that steel is not homogenous. The solid metal contains several constitutents to which names are given just as mineral constitutents are characterized one from another. The constituent that first forms when molten steel freezes is called *Austenite*, so that when the steel has entirely solidified after the freezing process, the whole mass is Austenite. The question, of course, arises as to what is the composition of this Austenite. There are two outstanding theories at present as to this composition; one maintaining that Austenite is a solid solution of iron and carbon; the other, that Austenite is a solid solution of iron and iron carbide, the carbon having formed a carbide of iron which in turn forms a solid solution with the remaining iron. The discussion of the pros and cons of these theories are of little practical interest. In the following, Austenite will be considered as a solid solution of iron and iron carbide, this carbide being represented by the formula Fe_3C. The term solid solution may be new to many and in consequence may cause a little confusion. The idea of one substance dissolving in another when liquid, is, of course, quite familiar. The term solid solution merely represents the fact that one substance dissolves in another when both are in the solid state.

Austenite, then, is a solid solution of iron and iron carbide. However, it is usual to give these two constituents distinctive names. Pure iron is referred to as *Ferrite* and iron carbide (Fe_3C) is called

Cementite, so that hereafter, *Austenite will be referred to as a solid solution of Ferrite and Cementite.* In order to investigate the changes that take place in the constitution of steel during cooling, it is advisable to take certain examples which are typical and follow out their cooling.

Considering first a steel containing, .2 per cent. of carbon, the changes that take place will be typical for all steels containing from

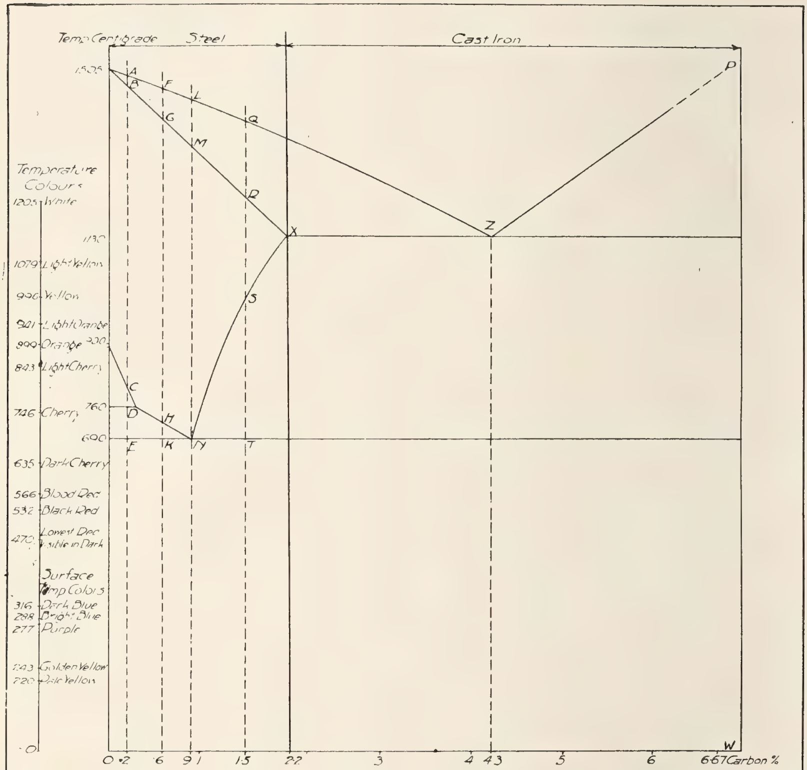


FIG. 1.

zero to about .4 per cent. carbon. The cooling of this steel is represented by the line *A.E*, Fig. 1. At *A*, freezing begins with the formation of Austenite. At *B* the metal is all solid Austenite. When the temperature corresponding to *C* is reached, Ferrite begins to segregate out of the Austenite and as the temperature drops from C to E more and more, Ferrite separates out. This ferrite that separates out is called *excess Ferrite*. At *E*, the remainder of the Austenite formation which now contains all the cementite, breaks up into its constituents, namely, Ferrite, Cementite, these two constituents forming in small plates side by side. This portion of the steel which breaks up into the formation last described is called *Pearlite*,

which we see is a formation of Ferrite and Cementite. The steel at E, therefore, is made up of small areas of Pearlite (Ferrite and Cementite intermingled with one another) surrounded by excess Ferrite which segregated out during the cooling from C to E.

As intimated before, it is the writer's intention to keep out as many of the intricacies as possible, but it will no doubt have been noticed that in following out the cooling of the above example of steel, that there was some change at D of which no mention was made. *Above D, the steel is non-magnetic, below D, the steel is magnetic.* Another allotropic change takes place at C, but this need not be discussed here.

Taking next a steel containing .6 per cent. carbon we have a sample typical of all steels containing between about .4 per cent. and about .9 per cent. carbon.

At F, Austenite begins to form and at G the metal is entirely solidified. At H the steel becomes magnetic and the excess Ferrite begins to segregate out of the Austenite. Between H and K the excess Ferrite continues to separate out; and at K, the remaining Austenite breaks up into its constituents, Ferrite and Cementite, giving the formation called Pearlite. The steel thus at temperatures below K is Pearlite surrounded by excess Ferrite.

With a steel containing about .9 per cent. carbon, solidification takes place between L and M. At N the steel becomes magnetic and the Austenite all becomes Pearlite.

The transformations for a steel containing 1.5 per cent. carbon will be typical for steels containing from about .9 per cent. to 2.2 per cent. carbon.

Between Q and R Austenite is formed. At S, on the line XN, Cementite begins to segregate out and continues to do so during the cooling from S to T, this Cementite being called *excess Cementite.* At T, the remaining Austenite becomes Pearlite. The steel below T is Pearlite surrounded by the excess Cementite.

It will be noticed that steels containing below .9 per cent. carbon are made up of Pearlite surrounded by excess Ferrite. Steels containing above .9 per cent. carbon are Pearlite surrounded by excess Cementite. Steel containing .9 per cent. carbon is all Pearlite, from which one would suspect that Pearlite by itself contains .9 per cent. of its own weight of carbon. This is true. When a steel has less than .9 per cent. total carbon, the Ferrite in the Austenite separates out by itself till the remaining Austenite contains .9 per cent. of its own weight in carbon, whereupon it changes to Pearlite. In steel containing over .9 per cent. carbon the Cementite separates out by itself taking with it considerable carbon, and when the remaining Austentite contains .9 per cent. of its own weight in carbon, it also changes into Pearlite.

From the foregoing, it is seen that steel contains two main constituents, Ferrite and Cementite, which group themselves in various ways to give the normal steel. Ferrite, being pure iron, is very ductile. Cementite on the other hand is extremely hard. Pearlite is a mixture of both Ferrite and Cementite, and one would

expect it to be strong and yet fairly hard. Taking these facts and applying them to the analysis of the physical properties of steels, one sees why low carbon steels containing as they do, a considerable quantity of excess Ferrite, are very ductile. As the carbon content of the steel grows, the steel contains more and more Pearlite and in consequence becomes higher in tensile strength but loses in ductility due to the lessening proportion of Ferrite. After .9 per cent. carbon is passed, the excess Cementite makes the steel harder and more brittle, the tensile strength also dropping off.

It must be clearly understood that the changes outlined throughout the above are those that take place under normal cooling. In other words, a piece of steel must be allowed to cool at a fairly slow rate if the normal conditions in the steel are desired. *Interference with the rate of cooling, such as chilling, for instance, will greatly effect the properties of the steel.*

The Grain Size of Steel

The granular structure of steel is best seen by observing a polished section under the microscope, although it is possible to get a comparative idea by observing the fracture, especially in the high carbon steels. Overheating steel above a certain temperature has a great effect on the grain size, and as grain size is more or less a direct indication of the strength and ductility of steel, it is important that the cures for overheating be understood.

The higher a piece of steel is heated above about 690°C. the coarser will be the grain size. (It may be pointed out that normally the grain size of low carbon steels is larger than high carbon steels). This coarsening of the grain size by overheating has the following effect: Low carbon steels lose in strength but do not seem to have their ductile qualities effected materially.

Medium and high carbon steels lose both in strength and ductility. Tool steels, for instance, when badly overheated become so weak as to be readily broken if tapped very lightly with a hammer.

The effect of overheating may be counteracted in two ways:—

(1) Work the steel mechanically as it cools from a high temperature.

(2) Heat refine the steel.

To apply the mechanical method, the steel must be forged or rolled as it cools. The effect may be roughly explained by saying that the forging or rolling breaks up the coarse grains. The mechanical work should theoretically be kept up till the steel has cooled to the temperature of the lines $C\ H\ N\ T$, Fig. 1, for if stopped at a temperature above this, the grain size will grow again till these temperatures are reached. The effort of engineers is to get the steel manufacturer to have the temperature at which rolling is completed as close as possible to these temperatures. In many cases, there is no doubt that the finishing temperature of rolling mills is too high, the result being a coarse grained and weakened steel. With forging, on the other hand, the work is generally continued to a lower temperature, as a forge hammer does not require as great an expenditure

of energy and consequently money, to produce the required effect as does a rolling mill.

If a piece of steel has been overheated and allowed to become cold, and it is desired to restore the grain size mechanically, it is only necessary to reheat the steel and forge or roll it.

It is seen that besides shaping a piece of steel, rolling and forging has another very important function, namely, *the production of strength by reducing the grain size of the steel.*

Obviously, there are many commercial steel shapes that do not lend themselves to work being done on them by either rolling or forging. Steel castings, for instance, furnish a good example. Many structural shapes also may be overheated subsequent to their manufacture, and in order to restore their grain size it would be impossible to forge them, much less roll them again. So then, if the grain coarsening effect of overheating is to be overcome, some other method must be resorted to. This other method is known as Heat Refining. In order to heat refine the grain size of a piece of overheated steel, the metal must first be cooled below 690°C. For low carbon steels from zero to .7 per cent. carbon, reheat the steel till the line *C H N* is reached. For high carbon steels from about .7 per cent. carbon up, reheat to about 725°C. The effect of this reheating is to break up the original coarse grain size and produce a new fine grain formation. Researches show that if a piece of steel be allowed to cool below 690°C., that on reheating a new grain formation starts on recrossing the temperature 690°, and this new formation of small grains will obliterate the old formation of large grains. This is a rough explanation, but it contains the principle of the process. As to the reason why the lower carbon steels have to be reheated higher than high carbon steels this would require more space for explanation than is at our disposal. The best practical example of the application of heat refining is seen in the heat treatment of steel castings. If it is necessary to make a low carbon steel casting of good ductility, it is usual to "anneal" it. Strictly speaking, "to anneal" means to slowly cool, but it is easily seen that *any amount of slow cooling will not refine the grain size.* A steel casting on cooling is extremely coarse grained, having cooled from a very high temperature above 690°C. In order to get a fine grained casting, it is always necessary to first cool below 690° and then reheat as explained above. Eye-bars for bridges are also often heat refined to make sure that the steel is as ductile and strong as possible. It is not out of place to point out here that there is a curious and persistent fallacy often expressed even to-day; namely that "vibration or shock will crystallize a piece of steel." There never has been any evidence that the grain of steel is coarsened by such treatment and to suppose that such treatment produces steel of a granular structure is an absurdity. Steel is always granular in formation. As to the growth of grain size due to such treatment, it is more than likely in every such case that the steel was coarse grained due to faulty manufacture and this fact was only discovered when the fracture occurred.

Generally speaking, no growth of grain size takes place below 690°C. However, there seems to be one exception to this in the case of very low carbon steels containing below .1 per cent. carbon. These steels if held for a long time at temperatures between 500°C. and 740°C. will have the grain size enormously enlarged and the metal becomes very weak. This phenomena is called "Stead's Brittleness" after J. E. Stead, who discovered it.

Burning of Steel

The external evidence of what is known as burnt steel is seen in the peculiar sparking of the metal at high temperatures. A slight amount of surface burning may not injure a piece of steel, but in any event the effect is certainly not beneficial. *Low carbon steels can be heated much higher without being burnt than can high carbon steels* such as used in tool making.

The burning is simply an oxidation of the steel. In badly burnt steel, the grains of steel become surrounded with oxide films, thus greatly and permanently impairing the strength.

Forging seems to do away with any injurious effect when the steel is only slightly burnt. This explains no doubt, why rivets which are often slightly burnt are not badly reduced in strength. However, as the writer heard one well known steel man say, the best way to do away with the bad effects of burnt steel is not to burn it.

Hardening Steel

Under normal conditions, the higher the carbon content of a steel the harder the steel. If a steel be heated to any temperature above 690°C. and cooled suddenly, it will become much harder than when in a normal condition. The rule quoted above as to the relation between hardness and carbon content also applies in this last case when cooling is accelerated. The higher the carbon content, the harder the steel will be when cooled suddenly. If the carbon content be below .2 per cent., however, it is doubtful if the increase in hardness of a steel cooled suddenly over a normally cooled specimen can be noticed by ordinary methods, such as testing with a file. Above this percentage of carbon the increase in hardness becomes more and more noticeable till the tool steels are reached.

In order to obtain the greatest possible strength with hardness, care must be taken not to heat a steel to too high a temperature above 690°C. It is true that hardening will be produced if cooled suddenly from any temperature above this, but it must be kept in mind that a high temperature above 690°C. will coarsen the grain size, thus reducing the strength. The best combined effect of hardening and strength is given at the temperatures of the line $C\ H\ N$ for steels below .7 per cent. carbon and at about 725°C. for steels above this percentage of carbon.

The rate of cooling is of great practical importance when hardened steel is desired. *The faster a steel is cooled from above 690°C., the harder it will be.* Quenching in ice brine gives a very hard

steel. Quenching in pure water at ordinary temperatures will harden the steel but not so much as ice brine. Quenching in oil gives a softer effect. By a judicious use of cooling medium, various degrees of hardness can be produced.

Tempering Steel

Tempering is a term nearly always misused. To temper a steel means to lessen the effect of hardening. Generally, the hardening and tempering are both classed together and referred to as tempering. *If a steel has been hardened, it may be tempered by being slightly reheated.* To understand the principle of tempering, what takes place during hardening must be investigated.

When a steel cools at a normal rate, we have seen that certain changes and adjustments take place. If the rate of cooling be hastened, sufficient time for these changes is not allowed and a condition which is not normal is brought about and maintained, the quick cooling making the metal too rigid to allow the normal changes to take place. At least this is a very satisfactory general way of viewing the situation. If now, the steel is slightly reheated, the rigidity of the metal is loosened and the normal changes will either be wholly or partly brought about, depending upon whether or not the steel be again quenched, thus again stopping the changes which may be taking place.

To summarize the tempering process; if a steel has been hardened, it may be either partially or wholly softened by reheating. The effect of this reheating may be stopped at any stage by simply cooling suddenly when desired.

A very convenient method of judging to what temperature a piece of steel has been reheated for tempering, is my means of observing the temper colours. If the surface of the steel be slightly polished it will be noticed that oxide colours form between 200°C. and 300°C. The temperatures corresponding to these colours are shown on Fig. 1. It is not necessary to reheat beyond any of these temperatures in order to temper a steel.

It may be pointed out that quenching in liquids, such as oil, which takes away heat slowly, gives practically the same effect as may be had by quenching in water and then tempering. When heat is abstracted by the oil, it is not taken away at such a rate as to entirely stop the normal changes from taking place. Cold water on the other hand, may almost entirely stop these changes, but the tempering allows them to slightly take place, thus arriving at the result obtained by oil hardening.

To illustrate the hardening and tempering of a cutting tool, the cold chisel gives a very good example. About one and a half inches of the tool are heated to a cherry red and then one half of this heated portion is quenched in water. The heat from the remainder is then allowed to flow into the quenched and hardened portion, thus tempering it. If the temper colours be observed, the

yellow will be seen moving slowly down to the point and the blue will be a short distance behind. This indicates the temperature of the steel and when these colours have gone far enough down the metal, the tool is quenched. Thus a good hard cutting edge may be obtained with the steel grading back to normal tough metal. The natural question at this stage is, when should the tempering be stopped? A very few trials will give the needed experience. If a cold chisel be taken and experimented with, the reader will very soon be able to judge for himself when to stop the tempering operation in order to get the proper hardness and toughness.

For rough work, the colours of the steel for given temperatures are shown on Fig. 1. This method of judging temperature by the eye is, of course, only good for rough work. When accurate results are required, pyrometers are used, and indeed, to attempt any other method would be out of the question.

PERSONALS

J. L. Alton is now with Highways Branch, Department of Public Works, Toronto.

E. T. Austin, B.A.Sc., '09, is with the Mond Nickel Co., Coniston, Ont.

E. G. Archer, B.A.Sc., '11, is with the Hydro Electric Power Commission, Toronto.

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G. A. Arksey, B.A.Sc., '15, with the Toronto Harbor Commission, Toronto.

W. F. M. Bryce, '08, is assistant engineer, city engineer's department, Ottawa, Ont.

G. G. Bell, '05, is chief engineer for West Pennsylvania Traction Co., 1st-2nd National Bank Building, Pittsburg, Pa.

J. H. Billings, M.A.Sc., '11, has received his degree of Master of Applied Science from both the Massachusetts Institute of Technology and Harvard University. Present address, Leskard, Ont.

D. C. Blizzard, B.A.Sc., '09, is at present at 16 Manor Road, Rugby, England.

W. V. Ball, B.A.Sc., '15, is shell inspector for Goldie & McCullough Co., Galt. His address, 40 West Main St. N., Galt.

V. A. Beacock, B.A.Sc., '15, is with the Hydro Electric Power Commission Toronto.

F. M. Buchanan, B.A.Sc., '15, is working on the Wayne County roads, Michigan. His address is 47 Goldsmith St., Detroit.

A. M. Campbell, B.A.Sc., '04, is erection engineer for the Toronto Structural Steel Co. Residence, Weston, Ont.

P. G. Cherry, B.A.Sc., '11, present address, 63 Pauline Ave., Toronto.

J. Clark, '00, is with the Turnbull Elevator Works, Toronto. His address is 129 Garden Ave., Toronto.

L. S. Cockburn, B.A.Sc., '10, has recently accepted position as heating engineer with the Glass Garden Builders, Toronto. His address, 201 Church St., Toronto.

J. Chalmers, '94, has been elected an officer of the Edmonton Branch of the Canadian Society of Civil Engineers for 1915-16.

Norman S. Caudwell, '10, of the town of Prescott and solicitor of the Supreme Court, has been appointed notary public in and for Ontario.

R. M. Cockburn, B.A.Sc., '15, is field draughtsman on the Toronto Harbor Commission.

A. B. Crealock, B.A.Sc., '18, is field draughtsman on the Toronto Harbor Commission.

Fred C. Dyer, B.A.Sc., '08, present address, 241 Melita Ave., Toronto.

E. V. Deverall, B.A.Sc., '15, with the Dominion Bridge Co., Toronto, as draughtsman.

MODERN MILITARY EXPLOSIVES

J. W. Bain, B.A.Sc.

The most casual reader of the newspapers must have noticed among the despatches from the front, such items as, "The French fired 30,000 shells in a two hours' attack," but it may be stated with certainty that few of those who glance over the reports have any idea of the elaborate preparation which must be undertaken before the shell is sent upon its death-dealing mission. Not only must the shell be very accurately made as far as dimensions and weight are concerned, but it must be propelled and burst by the use of materials which demand a tedious and very careful manufacture. It may not be out of place at this time to discuss these modern military explosives, during which brief discussion it is hoped that certain outstanding facts may be emphasized.

Gunpowder as it has been known to Europe for the last five hundred years, plays a minor part in the present conflict

The smoke which accompanies its explosion has a very obvious drawback from a military standpoint, and the concealment of guns, so strikingly shown in many illustrations recently published, has been rendered possible by the use of smokeless explosives. With the exception of small quantities of gunpowder used in the fuse of a shell and as a bursting charge in shrapnel, the powder of our fathers' days may be said to have been abandoned.

As a propelling charge in guns and rifles of all sizes, smokeless powders are almost universally used. These are mixtures of gun-cotton, nitroglycerine and a thick mineral oil such as vaseline; and a few words may be said as to their manufacture.

That an explosive oil could be obtained by mixing glycerine with nitric and sulphuric acids has been known since 1847 when an Italian chemist discovered the fact accidentally.

This substance, nitroglycerine, was, however, too dangerous to handle in its liquid condition, and Nobel conceived the happy idea of absorbing it in some porous material producing the familiar explosive, dynamite. The shattering property of the latter is well known to every one, and this material is consequently of no value as a propelling agent in a gun.

It was, however, discovered in recent years that if gun-cotton—which will be discussed later—were kneaded with nitroglycerine in the presence of a small quantity of acetone or camphor, there resulted a doughy mass which could be handled safely and at the same time worked up into a valuable propellant, exploding without smoke.

This is, in brief, the process of manufacturing the British *Cordite*, so-called because the dough is squeezed through dies under heavy pressure and reeled into cords which are afterwards cut to convenient lengths. The diameter of these cords is varied to suit the use for which the powder is intended, the larger the gun, the thicker the cord, and in some instances, the mass is moulded into large prisms or cylinders. Powders of this type varying slightly in composition, size and method of manufacture are used by all the

present combatants, and the supply must be adequate, or a retreat such as the Russians have just made is inevitable.

For the bursting charge in high explosive shells, picric acid or trinitrotoluol are the most widely used. Picric acid is obtained by the action of nitric and sulphuric acids upon carbolic acid, the latter a product of the distillation of coal tar. Under ordinary conditions, a yellow powder burning quietly in the open, melts at 122°C, and may be poured without danger in the shells where it solidifies as a dense yellow mass; such shells may be handled without special precaution and are prepared for use by the addition of a fuse. This consists of a somewhat elaborate timing device containing a thread of gunpowder which burns at a definite rate and leads to a small quantity of fulminate of mercury, which detonates violently on heating. The picric acid is curiously sensitive to such detonation and explodes with the greatest violence, liberating quantities of yellow fumes which are frequently referred to.

Trinitrotoluol is prepared by the action of nitric and sulphuric acids on toluol, a liquid hydro carbon, which, like carbolic acid, is a product of the distillation of coal tar. Trinitrotoluene burns quietly with a smoky flame, and only explodes violently when detonated with fulminate of mercury. It melts at about 80°C and can, consequently, be handled more conveniently than picric acid which melts at 122.5°; the latter has the additional disadvantage of emitting quantities of yellow, acrid fumes during the fusion which renders the loading process very unpleasant. Picric acid has also the drawback that it forms with many metals, highly explosive salts, so that for safety sake, the interior of the shell must be varnished, and the explosive is further protected by a paper lining. Trinitrotoluol does not suffer from these disadvantages. It may be interesting to note that the Dominion Steel and Iron Company at Sydney, B.C., are turning out about 500 gals. of toluol per day for the manufacture of this explosive, the final stages being carried out elsewhere; as far as the writer is aware, no picric acid has been made as yet in Canada.

For the destruction of bridges, earthworks, masonry, etc., and as a charge for torpedoes, gun cotton is widely used. This is made by the action of nitric and sulphuric acids on cotton, the product resembling closely the original fibrous material. After a very thorough washing, it is compressed into blocks and stored with a content of about 17% water. Like the two explosives mentioned above, it is fired with a fulminate charge; commonly a small amount of dry gun-cotton is also used, which permits the amount of the fulminate to be reduced.

These four explosives may be regarded as the most important in use at the present time; others are being employed without doubt, but their manufacture and properties cannot be considered here.

It will be noted that the raw materials used for the preparation of these four substances are as follows:

Sulphuric acid, Carbolic acid,

Nitric acid,	Toluol,
Glycerine,	Cotton,

and each of these will be referred to briefly in turn.

Germany has produced in recent years very large quantities of *Sulphuric acid.* To manufacture this substance, sulphur of some sulphides are essential; the former is not found native in quantities in the territory of the Dual Alliance. There are, however, considerable quantities of sulphides; and in the newly-conquered Belgium, the Austro-Germans have acquired control of large bodies of zinc blende, an ore in common use for the manufacture of sulphuric acid. It may be concluded, therefore, that the supply of this acid is adequate.

Nitric acid has until ten years ago, been made exclusively from sodium nitrate imported from Chile, where it is found native. This source being cut off, the Germanic Allies have had to fall back upon the nitric acid made from the air by electric furnace methods. The latter have been highly developed in Norway owing to the cheapness of water power, but there are well founded reports current that steam power is being used in Germany for the same purpose. Taking the most favorable yields which have been made public, one horse power year will yield 1¼ tons of pure nitric acid, and Norway's total production is estimated at 300,000 tons. When the enormous plant which would be necessary to generate 100,000 horse power by steam is considered, the writer is forced to the conclusion that only a quarter or a third of the requirements of the Germanic Allies can be produced within their own territory by the processes under consideration.

Ammonia can be converted into nitric acid and without difficulty and this is being done beyond question in Germany at present. No data are at hand which permits a calculation as to the output from this source, but for various reasons which cannot be detailed, the writer believes that 100,000 tons per annum is the maximum at present.

We have then a maximum probable supply of nitric acid sufficient for the manufacture of 1,000 tons of explosives per day.

Glycerine is obtained by boiling the natural fats or oils with caustic soda, or by treating these with steam under pressure. In 1912, Germany imported glycerine or its equivalent in fats to the extent of 19,000 tons; the loss of these imports can only be made up by oils or fats obtained in the territories of the Dual Alliance. Here, again it is difficult to estimate the available supply, but the writer believes that a shortage in glycerines is inevitable. It is not unlikely that substitutes for nitroglycerine in the manufacture of smokeless powder, will be or are being used, and the shortage alluded to above would not have any serious effect on the supply of munitions.

Carbolic acid and toluol, as has already been noted, are obtained from coal tar, or from coal gas. The conversion to the corresponding explosives is comparatively easy from a chemical standpoint, and here the Germanic Powers have a decided advantage. Everyone is familiar with the great coal tar dye industry of Germany, and their

great plants can be adapted for the manufacture of these explosives on a few days' notice. The same apparatus which is used in making the dyes, can with a few minor changes, be turned to the production of picric acid or trinitrotoluol, while the Allied Powers are forced to build many of their factories from the ground. The immense advantage which this has given to the Dual Alliance, shows only in more marked relief, their inability to deal the crushing blows which were to decided the issue.

Carbolic acid and toluol can be made in very large quantities in Germany and Austro-Hungary; there seems to be little prospect of the shortage in these substances. *Cotton* has been so prominent a factor in the maritime warfare that but little need be said. When the amounts of cotton in the possession of one household are remembered, it is not difficult to conclude that very large contributions can be made by private citizens should necessity arise, but here again the picture holds only the prospect of lessening supplies. Whether wood pulp or paper which like cotton, is almost pure cellulose, can be used in its place, still remains to be seen, but much can be done under stress, and gun cotton will not fail as an explosive for some time to come.

In conclusion, some data and calculations may be of interest. Sixteen cartridges for the British service rifle contain 1 pound cordite, or, 1,000,000 cartridges contain 31 tons. The French 75 mm. gun uses 5 pounds of explosives for each explosive shell; 100,000 shells involve the expenditure of 250 tons. A 12 in. British gun requires 189 pounds of explosives per shot, or 10½ rounds per ton of explosive,

The writer has amused himself in making some guesses as to the daily consumption of explosives upon the various battle fronts, with only the vague data of occasional reports as a basis. What quantities have been expended by the Germanic Allies in Galicia and Poland since May is even beyond guessing, for practically no information has appeared; we are merely informed that the consumption has been enormous. The impression which is produced in our minds is that exhaustion of the supply is approaching, but we must bear carefully in mind, that our journalists feed us sedulously with the most optimistic scraps of information, and that we have as yet no information, direct or indirect, that the Dual Alliance is failing or is likely to fail for some time to come in its supplies of explosives.

F. R. Ewart, B.A.Sc., '07, is a member of Ewart & Jacob, electrical engineers, Room 306, 156 Yonge St.

Gerald Galt, B.A.Sc., '07, is metallurgical engineer for the Braden Copper Co., Rancagua, Chile, South America.

Norman R. Gibson, B.A.Sc., '01, present address, 550 Confederation Life Building, Toronto.

J. M. Gibson, '10, is taking out his captaincy papers at Niagara.

Wm. W. Gunn, B.A.Sc., '09, present address 243 Quebec Ave., Toronto.

R. D. Galbraith, B.A.Sc., '15, is on mechanical designing for the Curtiss Aeroplane Co., Toronto.

G. D. Gray, B.A.Sc., '15, is inspecting shells for the Canadian Inspection Co. His address, 40 West Main St. N., Galt.

Geo. S. Gray, B.A.Sc., '15, is on harbor construction work for the Canadian Stewart Co., Toronto.

THE WORK OF THE ENGINEERING SOCIETY OF THE UNIVERSITY OF TORONTO AND ITS COOPERATION WITH THE FACULTY OF APPLIED SCIENCE

Dean W. H. Ellis, M.A., M.B.

The founders of the University College Literary and Scientific Society had in mind an organization for the discussion of subjects of interest to the students of both literary and scientific character, but the scientific side was always a dead letter and that body from the first became purely a debating society.

The late W. B. Murrich, M.A., LL.B., at one time president of the society endeavoured to stimulate the scientific side by giving a medal for a scientific essay, but without any permanent effect in changing the character of the Society.

In its own way and after its own fashion, the society played a very important part in university life. It afforded a means of social intercourse to the students, gave them opportunities of becoming acquainted with the conduct of public business and practice in public speaking, as well as other advantages of much value.

The students of the School of Practical Science recognized the value of such an organization and a band of enterprising and public spirited students, prominent among whom was Dr. T. Kennard Thomson, organized a society in the School in the year 1885. The first President being the Principal of the School, Professor Galbraith. Thus from its inception the Faculty and the students have been closely associated in the Engineering Society. As soon, however, as the Society was fairly on its feet, it chose a President from among the students and Mr. H. E. T. Haultain was elected to this position. From that time till now the President of the Engineering Society has been a student.

Although it has been implied that the idea of the Engineering Society was suggested by the University College Literary and Scientific Society, the former is no slavish imitation of its older sister, but was organized and has developed on quite distinct lines. It aims to be and is a professional society and its papers are all of a technical character, in most cases relating the experience of the author. A number of very valuable papers have from time to time been contributed by graduates and many good papers have been given by undergraduates, based on their vacation work.

In addition to this many useful and stimulating lectures have been given by engineers of eminence on subjects on which they were recognized authorities, thus giving the students a first hand acquaintance with the conditions of modern engineering as understood and practiced by its engineers occupying leading positions in this and other countries. The business meetings of the Society and its various committees afford to the student training and practice in the conduct of public business, which many of them have found of great value in after life.

Some years ago the Society undertook to sell to its members on the co-operative system the various instruments and materials

required by students of Engineering and this Supply Department has had a flourishing career for several years.

There is one feature of the Engineering Society which calls for special notice, this is its representative character. In a very special sense the Engineering Society may claim to represent the students of the Faculty of Applied Science, in fact the Engineering Society is an embodiment of the undergraduates of the Faculty of Applied Science and can speak for them with no uncertain voice. By a wise provision the fee for membership of the Society is included in the dues payable by each student to the Bursar, and hence every student in good standing is a member of the Society.

It may be assumed therefore with more than usual confidence that a resolution of the Engineering Society expresses the opinion of the undergraduates of the Faculty of Applied Science and the most direct way of reaching the ears of the student body is through the Engineering Society.

The existence of this thoroughly representative body with a democratic organization of its own, has been and is of the greatest value with regard to the relations between the teaching staff and the students of the Faculty.

Many things that cause friction between the governors and the governed do so because of mutual misunderstanding, the saying tout savoir est tout pardonner, though not the whole truth contains more thuth than most sayings of its kind, and any thing which helps to make clear to the student what the Professors really mean and to the Professors what the students really think is of the greatest value.

Ten minutes chat between an official of the Faculty Council and an officer of the Society will often clear up misunderstandings that might otherwise have become quarrels and developed into harshness on the one side and mutiny on the other.

The Engineering Society in this way is looked upon by the Faculty Council as a most valuable ally in the task of maintaining the orderly and efficient working of the academic machinery. It is and has been a power working in the interests of peace and good will.

In addition to all this the Engineering Society publishes a journal "APPLIED SCIENCE."

This is the most ambitious and perhaps on the whole the most creditable of its many activities. The Society may point with justifiable pride to the volumes of "APPLIED SCIENCE" which have appeared since its inception in 1907. Graduates and undergraduates, professors and students have joined in the endeavour to make this publication worthy of the University and of the Faculty which it represents and their labours have been rewarded with no small measure of success. No one who knows anything of the conduct of a periodical of this kind will be surprised to learn that its upkeep makes a heavy demand on the financial resources of the Engineering Society. To keep the journal up to the standard which its promoters have had in mind demands considerable effort and sacrifice on behalf of the Faculty of Applied Science and its friends. It is to the graduates of the university in Applied Science that the executive of the Engineering Society and the editorial staff must look for support in this undertaking and they confidently expect that they will not look in vain.

SHRAPNEL*

Similarities and Differences in Leading Types of Shells

Shrapnel shells, as used at the present time by the several governments, vary slightly in construction and general contour as well as in the constituents entering into their different members. A completed shrapnel, as illustrated, consists of a brass case carrying a detonating primer and the explosive charge for propelling the projectile out of the bore of the gun; a projectile, which is a forged shell carrying lead bullets and a bursting charge; and screwed into the front end a combination timing and percussion fuse which can be set so as to explode the shell at any desired point and from which the flame for exploding the bursting charges is conveyed through a powder timing train and a tube filled with powder pellets down through the diaphragm to the powder pocket.

Shrapnel shells are made in two distinct types, the common, and the high-explosive. The high-explosive shell is not ruptured upon the explosion of the bursting charge in the base, but the head is forced out and the bullets are shot out of the case with an increased velocity. In the meantime, the head continues in its flight and detonates on impact. This type of shell is not used quite so extensively as the common shrapnel, and for simplicity of description the latter alone will be taken up in the following.

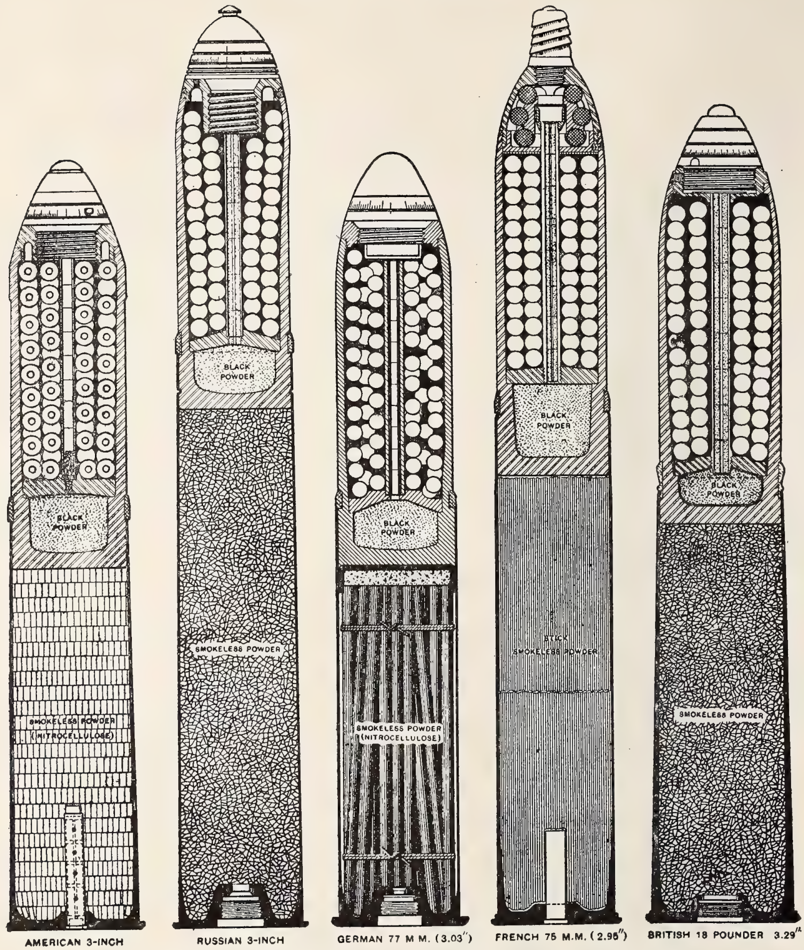
So far as the construction of the shrapnel shell and case is concerned, there is little difference in those employed by the various governments. The form of the explosive charge held in the brass case differs in almost every instance, but smokeless powder in some form or other is used. The detonating agent or primer held in the head of the case also varies in almost every type of shrapnel. Practically all primers are provided with "safety heads" so that the shrapnel can be handled without danger of premature explosion.

The shell itself, as previously mentioned, is made either from a forging or, in the case of American and French shells, from bar stock. Forgings, however, are used to a greater extent than bar stock, because the forged shell is more homogeneous in its structure than the bar stock shell, and piping is entirely eliminated. Near the base of all shells is a groove in which a bronze or copper band is hydraulically shrunk. This is afterward machined to the desired shape and takes the rifling grooves in the gun so as to rotate the shell when it is being expelled.

The bursting charge, common black powder, is carried in the base of the shell and is usually enclosed in a tin cup. Above this is the diaphragm which is used for carrying the lead bullets out of the shell when the bursting charge explodes and distributes them in a fan shape. In most shells, upon exploding, the nose blows out, stripping the threads that hold the members together. It will therefore be seen that, in the explosion, the entire fuse, fuse base, tube, diaphragm and bullets are all ejected, the shell itself acting as a secondary cannon in the air.

The range of a 3-inch shrapnel shell is about 6500 yards, and the

*Machinery.

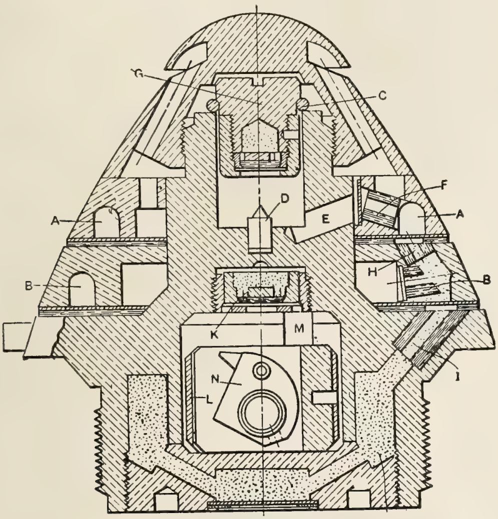


SECTIONS THROUGH TYPICAL SHELLS OF LEADING NATIONS

muzzle velocity of the quick-firing field gun ranges from 1700 on the American to 1930 feet per second on the Russian. The duration of flight ranges from 21 to 25 seconds. When the bullets are blown out of the shell by the bursting charge, they are given an increased velocity of from 250 to 300 feet per second. The velocity of the shrapnel at 6500 yards is about 724 feet per second. The number of lead bullets carried in the 3-inch shrapnel shells ranges from 210 to 360. In all cases, the lead bullets are about ½ inch in diameter, weight approximately 167 grains, and are kept from moving in the shell by resin or other smoke-producing matrix.

The matrix put in with the lead bullets, in addition to keeping them from rattling, is also used as a tracer. It is of importance in firing shrapnel that the position of the explosion be plainly seen. With large shells this is not difficult, but with shrapnel for field

guns at long range certain conditions of the atmosphere make it difficult to see when the shell actually bursts. Various mixtures are used to overcome this difficulty. In some cases fine grained black powder is compressed in with the bullets in order to give the desired effect. In the German shrapnel a mixture of red amorphous phosphorus and fine grained powder which produces a dense white cloud of smoke is used, and in the Russian, a mixture of magnesium and antimony sulphide is used.



American Timing and Percussion Fuse

The most common fuse is that known as the combination timing and percussion fuse of the double-banked type. This is used in practically all shrapnel fuses except the French. The manner in which the combination timing and percussion fuse is regulated to discharge the bursting charge in the shrapnel shell is interesting and involves extremely difficult mathematical calculations. Before going into the method of setting the fuse, it would probably be advisable to describe briefly just how the fuse operates. An example of the double-banked fuse is that adopted by the American government, here illustrated. The following description applies to this type of fuse.

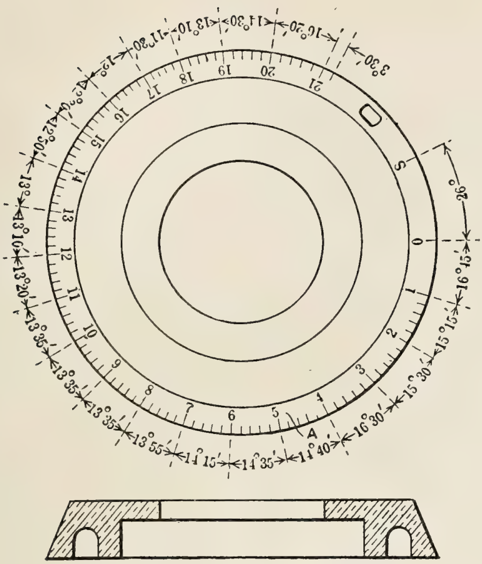
Assume first, that the timing ring is set at zero. The propelling force given to the shrapnel shell in leaving the bore of the gun is such as to sever the wire *C* from the plunger *G*. The plunger *G* carries a concussion primer which is discharged by hitting a firing pin *D*. The flame passes out through the vent *E*, igniting the powder pellet *F* and the upper end of the train A, and then through the vent *H*. From here, the flame is transmitted to the lower timing ring *B* through the vent *I* and the magazine *J*, and from there through the tube to the bursting charge in the base of the shrapnel shell.

Assume any other setting, say 12 seconds. The vent *H* is now changed in position with respect to the vent *F* leading to the upper timing train, and the vent *I* leading to the powder magazine *J* is also changed. The flame, therefore, now passes through the vent *E* and burns along the upper time-train *A* in a counterclock-wise direction until the vent *H* is reached. It then passes down to the beginning of the lower timing train and burns back in a clockwise direction to the position of the vent *I*, from which it is transmitted by the pellet of compressed powder in this vent to the powder magazine *J*. It should be understood that the annular grooves in the lower face of each timing train do not form complete circles, a solid portion being left between the grooves in the ends of each. This solid portion is used to obtain a setting at which the fuse cannot be exploded and is known as the "safety point." As shown it is marked *S* on the adjustable timing ring.

The timing fuse shown is of the combination timing and percussion type, and if the wire *C* fails to release the percussion plunger *G* the shell is exploded by means of a percussion fuse which comes into use when the shell strikes. The percussive mechanism consists of a primer *K* held in an inverted position in the centre of the fuse body by a cup located beneath the percussive primer. The percussion plunger *L* works in a recess in the base of the fuse body and is kept at the bottom of the recess away from contact with the primer by a light spring in the plunger *M*. The firing pin *N* is mounted on a fulcrumed pin, and is normally kept in the vertical position by means of two side spring plungers. When the shell strikes, the impact causes the plunger to snap up against the primer after compressing the spring in the pin *M*. This causes the firing of the primer *K* and the explosive charge passes out through a hole in the percussion plunger chamber, not shown, to the magazine *J* and from there down to the powder in the base of the shell.

With the exception of a few minor details, the timing fuses used in the American, Russian, German, Japanese, etc., shrapnel shells are the same. The French timing fuse, however, operates on an entirely different principle.

The timing ring used on the American fuse is illustrated. Here it will be seen that the ring is provided with 21 graduations corresponding to 21 seconds in the duration of flight of the projectile. It will also be noticed that the spacing of the graduations differs. For instance, *S* to *o*, or safety to *o*, occupies 26 degrees. This, as previously mentioned, is required so that the ungrooved surfaces of the timing rings can be swung around far enough to bring them in line with the vents for firing. From 0 to 1 is greater than from 1 to 2. The reason for this is also in the relation of the vents. From 3 to 4 will be seen another variation. This takes into consideration the positions of the lower timing train and the trajectory of the flying missile. From 6 seconds around to 18 is practically a constant drop, taking into consideration the decrease of velocity, and from 18 on, the graduations begin to increase for two reasons: the decrease in the velocity of the missile and the action of gravity.



AMERICAN TIMING RING

In manufacturing shrapnel shells, a test shell is taken from every 120 and is actually fired out of a quick-firing gun into a bank of sand. If the contour of the shell in the neighborhood of the powder pocket is expanded during this test, the shell is discarded because of the liability of tearing out the rifling grooves in the gun.

INTERNATIONAL ENGINEERING CONGRESS

Those of our readers who anticipate visiting the Panama Exposition, will do well to try and arrange to be in San Francisco from September 20-25 for the International Engineering Congress. Never has there been such a representative assemblage of engineers.

The materials of engineering construction will receive special attention and the field will be treated under eighteen or more topics, covering: timber resources; preservative methods; brick and clay products in general; life of concrete structures; world's supply of iron; life of iron and steel structures; status of copper and world's supply; testing of metals, etc.

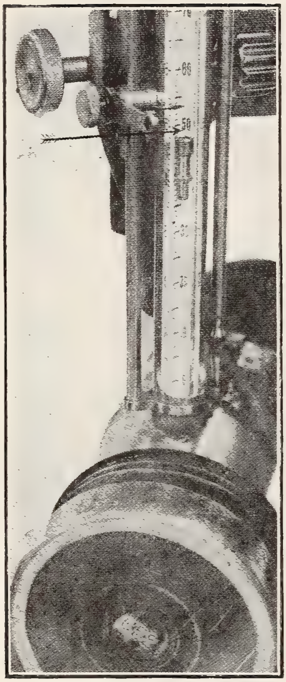
These papers will be contributed by engineers eminent throughout the world, and will be published as volume 5 of the transactions. This volume will form a most valuable acquisition to the library of all engineers and others who may be interested in these phases of engineering.

For further information and a copy of the booklet which outlines the programme and prices of the transactions, apply to

W. A. Cattell, Sec.,
417 Foxcroft Building, San Francisco, Cal.

THE SCLEROSCOPE

R. J. Marshall, B.A.Sc.



The supplying of munitions to England has introduced a great many new problems to the Canadian manufacturer. This business like any other special line of machine work has a whole host of difficulties which have to be overcome before the finished shells can be supplied with a certainty which means successful production.

Almost the first of these difficulties to be met and overcome in the production of shrapnel shells is the mastering of the heat treatment. The steel forgings have a tensile strength varying from 75,000 lbs. to 90,000 lbs. per sq. inch before the heat treatment. This stress is raised from 125,000 to 200,000 lbs per sq. inch by heating the shell to a temperature of about 1,500° F. and quenching it suddenly in oil at 100 °F. This operation would be simple if the treatment could be exactly specified and if the material had a uniform chemical composition, but unfortunately the steel cannot be produced uniformly enough to allow the treatment to be given in precise and definite terms. Therefore the manufacturer has had to gain his own experience by experimenting and sometimes by making mistakes. A treatment which would prove successful with .45 carbon would probably cause a steel of .55 carbon to fail in passing the physical specification. The manganese, sulphur, phosphorus, silicon and nickel are the other chemical constituents which must also be considered in selecting the treatment. Each variation in the chemical composition necessitates slight changes in the heat treatment.

It is unfortunate that during these critical times our Canadian manufacturers are compelled to learn the arts of munition making. Some English Parliamentarians have surely forgotten that experience in these arts is essential before production can be forced. This seems to be a reasonable explanation of why our manufacturers were not able at first to produce the quantity of shells desired.

To heat treat a shell is one kind of a problem, but to know what effect the heat treatment has had on the steel is another problem of an entirely different kind. The elastic and tensile properties are the standard of comparision, but of course it is impossible to cut selections from all shells for tensile tests, therefore the manufacturer

had to find some method of following the changes made by heat treating without damaging the surface of his shell. The instrument which has proved the most successful in this regard is the scleroscope.

The scleroscope consists of a small hammer with rounded diamond of known radius in the striking end, which is raised pneumatically in a glass tube to a height of about 11 inches. This is dropped on the surface to be tested and rebounds, the operator noting the amount of rebound on the scale attached to the glass tube; the reading on the scale is called the scleroscopic reading. The principle made use of in the calibration of this instrument is the physical relationship between the tensile and hardness properties of steel. A steel which has high tensile properties will offer a harder surface to the impact of the hammer than one which is low in tensile strength and the harder of the two surfaces will give the greater reading.

Some of the scleroscopes have a scale of tensile strengths opposite the scleroscope scale, but the tensile scale is not at all to be depended upon for reasons that will be outlined later in this article. It becomes necessary then for the operator to calibrate the scleroscope scale relating his readings to tensile tests. Pieces which have been carefully scleroscoped and which range in reading from say 35 to 55, are made into tensile test pieces and tested in tension. By comparing tensile strength with the War Office specification the safe range is found and that is compared with the corresponding scleroscope readings.

The scleroscope reading of 45 for instance, is not by any means an infallible indication of a definite tensile strength. If for example, the hammer is dropped on the same spot a number of times successsively, higher readings will be obtained. The first drop of the hammer makes a small mark, and succeeding readings enlarge the area. The amount of rebound is a function of the area of the indentation made; as the area increases the rebound will also increase.

The smoothness of the surface on which the hammer is dropped has also a bearing on the height to which the hammer will rebound. A rough surface will not give as great a reading as one perfectly smooth. Also the rebound depends upon how the piece being tested is placed under the scleroscope. If it is loosely placed on a light anvil, the reading will not be as great as if placed in a solid holder. The chemical composition of the steel also effects the reading obtained. For one set of chemical figures a reading of 45 on the scleroscope would represent a stress of say 130,000 lbs. per sq. inch, but for a different chemical composition the scleroscope reading of 45 might represent only a stress of 110,000 lbs. per sq. inch.

These fallacies in the scleroscope are submitted as evidence supporting the contention that the instrument is an aid to a close inspeciton of the steel, but it should not be taken as an infallible method of testing the tensile properties of the shell. Properly calibrated and frequently checked, the scleroscope should be indispensable to the business of producing shell.

UNIVERSITY OF TORONTO CLUB OF NEW YORK

On the evening of April 22nd, the University of Toronto Club, of New York, held its annual meeting, which was preceded by an informal dinner.

During the meeting attention was called to the notice recently sent out in regard to the University of Toronto Military Hospital, equipped for service at the front, and a committee appointed of which Mr. W. J. K. Vanston was elected chairman. The meeting was brought to a close with reports from E. W. Stern, '84, J. S. Galbraith, B.A.Sc., '13, and others, on the work being done by the University students and graduates in connection with the war. Mr. Stern's remarks related largely to the work of C. H. Mitchell, '92, at the front, while Mr. Galbraith spoke more particularly about military affairs at Toronto.

Among those present were: President Louis L. Brown, '95, and past presidents, Dr. T. K. Thomson, C.E., '86, T. H. Alison, B.A.Sc., C.E., '93, H. F. Ballantyne, B.A.Sc., '94, E. W. Stern, '84.

After the routine business the following officers were elected for the year 1915-16:—President, Dr. E. R. L. Gould; vice-presidents, Mr. C. V. Campbell, Mr. John Langton, Dr. R. G. Snider; secretary-treasurer, Mr. H. F. Ballantyne, '94; membership committee, Dr. J. E. Bowman, H. P. Rust, '02, and A. LeR. Chipman.

Mr. H. F. Ballantyne is following the example of Dr. T. K. Thomson, as he has been appointed secretary-treasurer for another year.

EXAMINATION SUPPLEMENT

Fourth Year—A. H. MacQuarrie is now eligible for the degree of B.A.Sc.

Third Year—H. R. Hopkins and C. E. Gage have completed the third year examinations.

B. B. Hogarth, B.A.Sc., '14, is assistant engineer on the Alberta and Saskatchewan Power Survey, Water Power Branch, Ottawa.

H. O. Hill, B.A.Sc., '07, now at 315 Western Ave., Aspinwall, Pa.

Chas. T. Hamilton, B.A.Sc., '07, is a member of the firm of Johnston & Hamilton, engineers and contractors and Dominion and B.C. land surveyors, 73 Exchange Building, 142 Hastings St. W., Vancouver.

A. N. Hunter, B.A.Sc., '08, is connected with the Canadian Inspection Co. at Detroit. His address is care of Detroit Rounding Co., Jefferson Ave. W., Detroit.

W. T. Hall, B.A.Sc., '15, has accepted a position with the Braden Copper Co., Rancagua, Chile, South America.

L. T. Higgins, B.A.Sc., '15, has also gone to South America with the Braden Copper Co., Rancagua, Chile.

C. E. Hogarth, B.A.Sc., '15, is reinforced concrete inspector on the Welland Ship Canal at Port Weller.

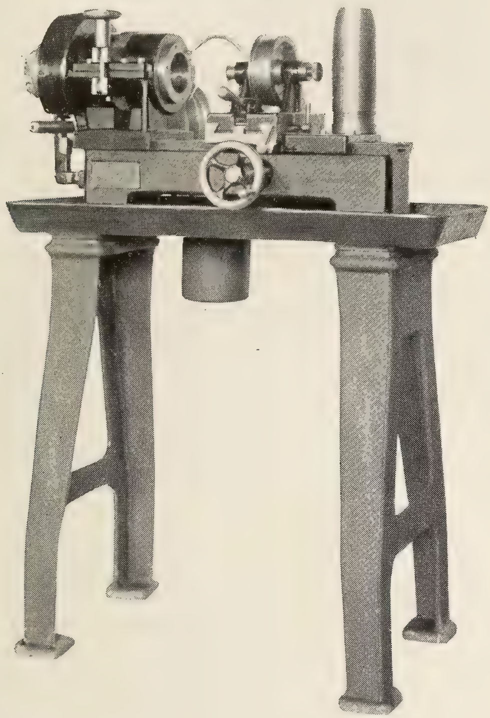
L. G. Ireland, B.A.Sc., '07, has been appointed manager of the Brantford Street Railway in addition to the office which he has previously held as manager of the Hydro Electric System of Brantford.

R. V. Jones, B.A.Sc., '15, is inspector for the Beaver Mine.

R. H. Johnston, B.A.Sc., '10, now residing at 10162 116th St., Edmonton, Alta.

A NEW THREAD MILLING MACHINE FOR HIGH EXPLOSIVE SHELLS

THIS machine has been developed by a Canadian manufacturer, and sold very rapidly to all leading shell manufacturers. It occupies a floor space of 2 feet by 3 feet and stands 4 feet high. The shell is placed inside the revolving spindle and automatically centred. The cutters are made of high speed tool steel and are of special design,



which eliminates the change of form when sharpened, and mills the top of the thread as well as the depth. It is fitted with an oil pump and fully equipped for work. This machine eliminates all risk of having shells rejected because of stripped threads, as is so often the case when tapped by the old method.

One operator can run several machines, as they are almost automatic. The output is greatly increased by having two machines, one to thread the nose and one to recess and thread the base. A perfect thread is produced in the nose in 2½ minutes, and the base recessed and threaded in the same time. These two machines will finish a shell every 2½ minutes, or 240 in a day of 10 hours.

UNKNOWN ADDRESSES

Our readers will confer a favor if they will kindly advise us of the correct, or most recent known address, of any of the men listed below

Acres, H. G., '14.
Alexander, J. H., '04.
Beatty, W. G., '01.
Berry, E. W., '10.
Bertram, G. M., '01.
Binns, R. E., '13.
Blair, W. J., '02.
Boswell, W. O., '11.
Bowman, A. M., '86.
Brackenreid, '11.
Brown, D. B., '88.
Brown, H., '11.
Brown, E. W., '09.
Bruce, W. J., '07.
Burnham, F. W., '04.
Cameron, M. G., '09.
Campbell, A. J., '04.
Campbell, A. W., '06.
Campbell, J. E., '08.
Campbell, R. J., '95.
Carey, B., '99.
Carscallen, H. R., '08.
Chambers, E. V., '14.
Chantrell, E., '05.
Charlebois, J. P. C., '08.
Chisholm, D. C., '10.
Christie, F., '06.
Clendenning, A. C.
Coulter, G. P., '07.
Darroch, J., '08.
De Guerre, F. C., '11.
Derham, W. P., '09.
Dowling, F., '05.
Elliott, J. C., '99.
Evans, J. H., '11.
Evans, S. D., '07.
Flynn, C. C., '11.
Foreman, W. E., '99.
Forester, C., '93.
Francis, C. C., '08.
Galletly, J. S., '07.
George, R. E., '03.
Gourlay, W. A., '03.
Heebner, M. B., '11.
Horton, J. A., '03.
Hull, H. S., '95.
Johnston, G. K., '03.
Jones, G. R., '06.
Kean, D. J., '09.
Keefer, A. H. E., '09.
Keys, W. R., '08.
Killip, W. C., '08.
Lawson, W. L., '92.
Lott, A. E., '87.
McCuaig, O. B., '04.
Macdonald, F. R., '08.
Macdougall, A. C., '01.
McKay, A. G., '07.
McKay, J. T., '02.
McKenzie, D. W., '05.
MacLachlan, W. A., '09.
McLean, W. N., '05.
McLeod, G., '09.
McMordie, H. C., '08.
McPherson, J. A., '06.
Macpherson, N. W., '09.
McTaggart, A. L., '94.
Maisonville, A. W. R., '10.
Malone, J. E., '08.
Martin, F., '87.
Matheson, W. C., '01.
Maus, C. A., '03.
Mennie, R. S., '02.
Milligan, G. L., '08.
Mitchell, L. C., '11.
Montague, F. F., '06.
Munro, F. V., '03.
Murray, J. D., '07.
Niebel, E. H., '11.
Nourse, A. E., '07.
O'Brien, E. D., '05.
O'Gorman, C. A., '09.
Oliver, J. P., '03.
Parke, J., '04.
Paton, T. K., '07.
Paulin, F. W., '07.
Pearce, K. K.
Pearson, C. L., '11.
Pope, A. S. H., '99.
Raymond, D. L. C., '04.
Roaf, J. R., '00.
Robertson, D. F., '03.
Sanders, W. K., '06.
Sauder, P. M., '04.
Scott, W. A., '06.
Shipley, A. E., '98.
Shortt, J. H.,
Smiley, R. W., '97.
Smith, J. H., '03.
Squire, G. E., '11.
Stamford, W. L., '08.
Stuart, J. L. G., '07.
Szammers, C. F., '11.
Taylor, J. W. R., '08.
Taylor, W. V., '93.
Thomas, V. C., '08.
Thomson, J. E., '06.
Williamson, D. A., '98.
Wilson, F. F., '09.
Wilson, W. H., '10.

Editorial

In a subsequent issue of Applied Science the management intend outlining definitely the policy of this magazine; and in the meantime propose, by a plebiscite, to deal with the advisability of continuing to publish Applied Science, and methods of making it a more effective and efficient medium among "School" men. A very worthy suggestion has come from a member of class 1903 and it is our intention to act upon it. Special editions of Applied Science will be published every three months, as special year numbers, devoted to articles contributed by members of that year. Each year will be advised through these columns, from three to six months in advance of the date of publication, of their issue, and as many as possible communicated with by letter.

SPECIAL ISSUES —ATTENTION CLASS 1903!

The first special issue will appear in November and will be got out by class 1903; and each and every member of that year is asked and being depended upon to contribute his share. Do not think that we will have enough material without yours, and that you are too busy. Every man can write an article on some line of work, if not engineering, he can contribute some current or personal news.

In order to avoid duplication of articles by different members in the same issue a date will be set in the letter each will receive, at which date the editor will require the names of the articles to be contributed.

It is to be generally understood by all our graduates that these special numbers will appear every three months and any year may be called upon at any time. The friendly rivalry and competition thus created among the different years should result in a great deal of added interest in Applied Science and in subsequent issues becoming better.

In each issue of Applied Science appears a full page advertisement asking graduates to send in their name and particulars of experience, but few have done so. So few, indeed, that one would think that all had work, or at least were satisfied with what they had. This, in normal times, is scarcely ever the case, much less in the present crisis. There are many without work at all and many not satisfied with what they have, and still the help of the Engineering Society is not solicited.

EMPLOYMENT BUREAU

The employment bureau has been reorganized and can, with the co-operation of the graduates seeking employment, be made of great value. On the other hand a file having but a few applicants for employment is worse than none at all. Conditions are improving as the following will show. During June and the early part of July we could have placed a School man as mine surveyor in Ontario, as assayer in Quebec, as mechanical designer, as assistant electrical engineer on city of Toronto Rapid Transit, as mechanical engineer

with Underwriting Company, a mechanical man as editor of a Canadian mechanical journal, and others, which we had to let go after going through our files and finding but few graduate applications in each section. This is a very regrettable fact, particularly this year, as many men would be glad of such positions, and it is very poor advertising for the Faculty of Applied Science and the Engineering Society.

The Editor has got in touch with the British representative, at present in Canada securing mechanics and engineers for munition work in Great Britain, and in the near future expects to place a large number of such men. Should any of our graduates desire such work or further particulars, it is advisable to make application at once to the editor.

SUBSCRIBERS IN ARREARS

All subscribers to Applied Science in arrears have received two circular letters during the past two months, in which the financial position of the Society was set out as fully as was consistently possible, anticipating that all would realize our situation and pay their dues. However, the response was very meagre indeed. So meagre, in fact, that there must be some reason.

It may be that in the rush of work the bill has been set aside with all good intentions and forgotten, as it is such a small amount. On the other hand it may be that you have received the magazine so long without being asked to subscribe that you began to feel that you were entitled to it as a graduate, and that you do not feel disposed to pay for something you had not asked for. If this latter is the case and you would be kind enough to advise us to discontinue sending the magazine to you, the Editor will write off your arrears. In offering to do this the management feel sure that few of our graduates view it in that light, although it must be acknowledged that it was poor business to let the matter run as it has.

There are others who, as life members of the Engineering Society, have expected all publications of the Society, and no doubt have been somewhat at a loss to understand why they should be billed for the magazine. In explanation, it might be said that this particular section of the constitution was changed some years ago, so as not to cover a life subscription to Applied Science, and it is to be regretted that members affected by this had not been advised. In the light of this explanation there is no doubt that everyone will only be too glad to pay up.

The management are sparing no pains to get, methodically, the general opinion of all our graduates on Applied Science and thereby hope to greatly increase the efficiency of the magazine in consolidating that "School" spirit of which we are all so proud. Not one can afford to be without this paper; but all our subscribers must be paying subscribers or something radical will have to be done.

As a result of the considerable correspondence of late in the technical and lay press on cast iron shells, we have been striving to

get an explanation of why the Allies do not use cast iron shells as the Germans are doing, and thereby increase our output. To those unable to apply critical examination this method of production may seem highly desirable. However, "The Engineer" of recent date contains an editorial, the deductions of which are based on an actual and critical examination of a piece of a German cast iron shell and raises the following objections, which are very interesting and instructive.

CAST IRON vs. STEEL SHELLS

"There are several objections to such shells. In the first place, where shrapnel is concerned, the number of bullets is reduced because the walls of the projectile must be made much thicker. In the case of high-explosive shell, this does not apply in so great a degree, because the walls of the steel shell are then made thicker than is necessary for strength, but there is such danger of a cast iron shell developing cracks during manufacture that high explosives cannot safely be used in them. It must be remembered that no risk of a shell bursting in a gun must be run, and no one will doubt that there is more risk in cast iron than there is in forged steel.

"Another point against cast iron is connected with accuracy of fire. To ensure this, the projectile must be perfectly in balance. The walls must not only be of exactly the same thickness all round, but they must be homogeneous. At the very high speed of revolution set up by the rifling, a small difference of weight to one side of the centre line would be quite sufficient to cause irregular shooting. With forged steel there is little or no difficulty in securing this balance; with cast iron there is always some danger of local porosity, which, besides being a source of weakness, would destroy accuracy.

"Moreover, if the projectile were cast on a chill core and was not machined internally, a risk of the core not being absolutely concentric would always have to be faced. Accurate fire would then be impossible. To remove a chill core, even if it were collapsible, it would be necessary to have a large hole in the base of a high explosive shell, of which the point is always solid, which subsequently would have to be plugged. If a sand core were used it might be removed through a smaller hole, but the machining of the interior would be difficult owing to the shape of the ogival head and the smallness of the hole through which the tool must be entered. In the case of shrapnel the boring would be much easier, because a large opening is left for filling purposes, but, owing to the small number of bullets that could be carried, cast iron shrapnel cannot be considered.

"All these facts have militated against cast iron shells, and although, of course, cast iron and cast steel were used at one time, they have entirely given place to forged steel. Furthermore the methods of manufacture of steel shell have been so developed that such shell can actually be turned out more quickly than those of cast iron of equal reliability and accuracy. An 18-pounder shell for example, can be completely machined from the bar in about forty minutes. The case for the forged steel shell is, then, complete, and there is no case at all for the cast iron shell.

A Case of Necessity

"The answer is fairly obvious, as to why Germans are using cast iron shells. In spite of the greatness of the supplies of their modern guns and projectiles, the Germans are beginning to find them not inexhaustible under the tremendous drain that is being put upon them. Hence, guns and projectiles have been drawn from stores many years old to fill up the deficit in modern supplies. The guns use a lower powder pressure, which the cast iron is able to stand, and the shells are probably filled with black powder, so that less danger is to be feared from an accidental burst. We believe this to be the real reason for the fragment of a cast iron shell being found on the battlefield.

"Whether the Allies also are using old guns and shell we cannot say, but it is not inherently improbable. Every nation concerned has been surprised by the part artillery has been called upon to play, and it is not unlikely that all of them have drawn upon resources of every kind that can be turned to account. If the Germans are indeed using cast iron, it is a favorable sign, for it shows that even they, with all their preparation, were unable to collect enough material of a modern kind to meet the requirements of the war.

However there are those who do not deny the impossibility of firing a cast iron shell accurately but believe that it might be used effectively to break down trenches, etc.

A GRAND PRIZE

We take great pleasure indeed in drawing to the attention of our readers the fact that one of our advertisers has received the only medal of honor awarded for rail joint products in the Transportation Department by the Panama-Pacific International Exposition at San Francisco. We refer to the Rail Joint Company of New York.

SUPPLY AND DEMAND

The Wall Street Journal of recent date contained comparative figures showing the remarkable increase in the cost of the various munitions of war. Most of the prices it quoted are the same as those at present prevailing in Canada, and as will be seen, are causing considerable concern to the military authorities. Powder has increased in cost over 25%, rifles approximately 50%; and other ammunition 30%. Unless the supply of such commodities as copper, antimony, lead, the acids, etc., which are necessary for the manufacture of these, is increased, there will be still further advances. For spot or early delivery almost any price can be obtained.

We notice the greatest rise in picric acid, which is used in enormous quantities in the manufacture of the French powder, melinite; the British explosive, lyddite, and the Japanese powder, shimose. In fact every grade of powder which has salt petre as a constituent

shows a sharp advance, as do all the explosive acids, with the exception of nitric acid.

On the other hand, however, dynamite which is used extensively for war purposes, has not increased in cost, but this may be due to the fact that it is more or less an article of commerce.

KEYS—BASSENBERGER

Conrad Roy Keys, B.A. Sc., '15, to Alvena Dorothea, daughter of Mr. and Mrs. Frank Bassenberger, of Berlin, Ont., at Toronto, April 13th, 1915. Mr. and Mrs. Keys will probably reside in Toronto.

ROBERTSON—MacKAY

At the home of the bride's parents, Weston, Ont., on June 2nd, 1915, Arthur S. Robertson, B.A. Sc., '14, son of Mr. and Mrs. S. Robertson, Toronto, was united in marriage to Irene, daughter of Mr. and Mrs. P. J. MacKay.

HOWARD—LOUDON

We have to announce the marriage of Mr. John T. Howard, B.A. Sc., '13, son of Mr. and Mrs. Willson Howard, of Madison avenue, with Miss Ruth Loudon, daughter of Mr. and Mrs. W. J. Loudon. Mr. and Mrs. Howard have gone to the States and after a holiday up the Georgian Bay will settle in 223 St. Clements avenue, Toronto.

MUNTZ—WELLER

Eric Percival Muntz, B.A. Sc., '14, son of the late V. G. Muntz and of Mrs. Muntz, Toronto, to Marjorie Louise, second daughter of Mr. J. L. Weller, engineer in charge of the Welland Ship Canal, at St. Catharines. Mr. and Mrs. Muntz will reside at Port Weller.

ON ACTIVE SERVICE

W. P. Murray, B.A.Sc., '08, has joined the Canadian Overseas Railway Construction Corps.

R. H. Hopkins, B.A.Sc., '06, has been appointed signalling officer of 39th Battalion at Belleville.

C. V. Perry, B.A.Sc., '14, with the 2nd Canadian Contingent in the Cyclist Corps.

Lt. J. L. Whiteside, B.A.Sc., '10, with 46th Battalion at Sewell, Manitoba.

Corp. A. T. McPherson, '16, **Pte. G. S. Stratford,** '16, **Lieut. D. G. Hagarty,** '16, **Pte. J. A. Simmers,** '18, **Pte. P. A. Laing,** '05, **O. G. Lye,** '14, with the Second University Overseas Contingent.

Lieut. L. S. Adlard, B.A.Sc., '15, is at Niagara Camp on the staff looking after the water supply.

E. R. Grange, B.A.Sc., '15, formerly on mechanical designing with the Curtiss Aeroplane Co., Toronto, has enlisted for active service with the Aviation Corps.

Lieut. Col. C. H. Mitchell, '92, has been recommended by Sir John French for distinguished conduct.

Lieut. H. F. H. Hertzberg, '07, of the Canadian Engineers, who was reported as wounded in the last issue, has recovered and just recently returned to the front. He has been mentioned in dispatches from the front and has been awarded the Military Cross.

Lieut. Elliott A. Greene, '11, of the 9th Battery, Canadian Artillery, has also been recommended by Sir John French for Distinguished Conduct.

Charles Cotton, '15, with the Montreal Battery, has received a commission in recognition of his fine work at Langemarck and has been recommended for the D.C.M.

CASUALTIES

Lieut. Fred T. Nicholl, '10, Eleventh Battalion, has been reported wounded.

Pte. F. W. Clark, '12, Fourth Battalion, is wounded.

Sgt. C. B. Ferris, '13, of the 2nd Field Company of Canadian Engineers, wounded at Langemarck. He was the only original sergeant left after this battle.

Lieut. Andrew J. Gray, '13, Sixteenth Battalion, wounded.

Lieut. Ian MacIntosh Sinclair, '17, Thirteenth Battalion, wounded.

Lieut. Angus N. Worthington, '11, Thirteenth Battalion , wounded.

Capt. J. G. Helliwell, '10, First Battalion, wounded.

D. D. James, B.A.Sc., '89, and **O. S. James, B.A.Sc.,** '91, are now residing at 6 Leuty Ave., Toronto.

K. A. Jefferson, B.A.Sc., '15, is with the Canadian Inspection Co. Resides at 40 West Main St. N., Galt.

E. W. Kay, B.A.Sc., '07, now resides at 517 Bannatyne Ave., Winnipeg.

C. R. Keys, B.A.Sc., '15, on mechanical designing for the Curtiss Aeroplane Co., Toronto.

J. Lanning, B.A.Sc., '11, is surveyor and estimator on the construction of the Whitby Hospital for the Insane. His address is Box 673, Whitby, Ont.

R. E. Laidlaw, B.A.Sc., '15, is foreman on Trent Canal for the Interior Construction Co. His address, Burndick, Ont.

R. A. McLellan, B.A.Sc., '11, is resident engineer for Murphy & Underwood, Ross Building, Saskatoon.

F. S. Milligan, B.A.Sc., '10, is with the Railway Department, city of Toronto. Residence, 33 Rathnally Ave., Toronto.

W. MacLachlan, B.A.Sc., '06, with the Electric Power Co., Confederation Life Building, Toronto.

W. R. McCaffrey, B.A.Sc., '15, is in charge of a party on irrigation work for the government in Western Canada.

E. V. McKague, B.A.Sc., '15, is resident engineer on the Rapid Transit Commission, Toronto.

DIRECTORY OF THE ALUMNI

Flynn, C. C., '11, was in Chicago, with the Western Electric Co., Limited, when last heard of.

Follett, R. C., '10, has no address upon our records except his home address, Oakville, Ont.

Foote, F. F., '13, is at Merritton, Ont.

Forbes, D. L. H., '02, is chief construction engineer for the Chile Exploration Co., Chuqicamata, Chile, South America.

Ford, A. L., '04, is government inspector and engineer, Department of Railways and Canals, at Prince Rupert, B.C.

Foreman, J. L., '14. His home is at Collingwood, Ont.

Foreman, J. M., '10, whose home is in Lucan, Ont., has no business address with us.

Forman, W. E., '99, was in Pittsburg with the Westinghouse Electric & Mfg. Co., construction department, when last heard from.

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